WHY AND HOW TO PROMOTE INTERDISCIPLINARITY IN RESEARCH AT THE UNIVERSITY?
from epistemological to practical aspects

Pierre Dos Santos (MD – PhD)
University of Bordeaux

What is interdisciplinarity?

It is traditional to consider three different modes of cooperation between different scientific disciplines according to their degree of integration.

The multidisciplinary approach consists in having several disciplines co-operate without emphasizing a collective work of integration and synthesis of language, concepts, tools or information specific to each. The research problem is "fragmented". Each specialist (or “hyperspecialist”) addresses an "autonomous" research object, related to this problem, according to the modalities specific to his discipline of origin. This generally results in a juxtaposition of the data produced in each discipline. A coordination work is then necessary to gather all the data produced by the specialists of the respective disciplines and to give back body to the treated problematic.

The transdisciplinary approach aims to transcend the boundaries of each discipline and to bring together knowledge beyond these borders. It sets itself *a priori* objectives of cooperation between disciplines more "ambitious" insofar as this cooperation is likely to go as far as transcending or transgressing these borders. Its essential principle is therefore a refusal to break down the problem of research treated along the borders specific to each discipline. It is a matter of defining a research object that does not belong to a given discipline and to construct contents and methods that are specific to the problematic defined.

The interdisciplinary approach is a process that emphasizes the development of the capacity of a multidisciplinary collective to conduct a work of analysis of integration and synthesis from the perspectives of several disciplines and therefore to install itself as an interdisciplinary team. The National Academies in the USA have defined interdisciplinary research as: " *a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice*.” The aim here is to deal with a problematic as a whole, by identifying and integrating all the relationships between all elements invloved. This new capacity makes it possible to link the disciplinary approaches *a priori* according to the research problem addressed and thus to place it in a broader systemic context. From the "pragmatic" point of view, interdisciplinarity refers to a research practice according to which:

- open and competent specialists in their respective disciplines work as a team to co-build a problem or a research object and make recommendations to solve or address it in a common language;
- open and competent specialists in their respective disciplines bring their experience, disciplinary knowledge, concepts, methods and instruments to work in an interaction that is at the heart of the project.

	Multidisciplinarity	**Interdisciplinarity**	**Transdisciplinarity**
Verbs characterizing the approach	Juxtapose Sequence Coordinate	Integrate Interact connect Concentrate/Synthetize Mix	Transcend Transgress Transform

The need for interdisciplinarity

Polemics of the seventies and eighties, sometimes violent, which opposed, especially in social sciences and humanities, the proponents of monodisciplinarity to those of multidisciplinarity are now over. A time when it was recommended to avoid mentioning interdisciplinarity or transdisciplinarity at the risk of being denied the label of "scientificity". When it was prudent to claim that the rigor of the scientific approach required a great specialization, that it could be achieved only within circumscribed conceptual frameworks proceeding from well-defined postulates or hypotheses, by means of tools of analysis specific to each discipline. Many symposia and books have since addressed in details the questions of multidisciplinarity and Interdisciplinarity in research and show the concern, if not the need, to bring together different scientific disciplines, at least because of the growing complexity of knowledge and the issues that science addresses.
Indeed, the most important issues facing science and society can not be solved by researchers working in isolated scientific disciplines:

- How can human societies generate enough energy to meet human needs without causing irreparable damage to the planet?
- How do individual DNA sequences interact with environmental factors to influence the incidence of a disease?
- How does the transmission of electrical signals between neurons generate a set of subtle and complex behaviours?
- What will be the impacts of changes in the Earth's atmosphere on the climate, glaciers and oceans?
- What combination of biological, environmental and social factors is causing the increase in obesity rates seen in many parts of the world?
- How can innovations in agriculture feed a growing human population?
- How can human societies act to provide a better framework for integration, fight against inequalities and promote economic development?
- How to understand the diversity of cultures, their historical depth, their languages, their social and institutional structures to better understand the dynamics that cross them?
- How to take into account individual behaviour towards risks and social attitudes towards progress, research and science?
- How to promote and support the adaptation of the entire population to the transformations of society?
- ...

These scientific questions, and many others, are inherently interdisciplinary. They require the collaborative efforts of scientists with different disciplinary cultures, knowledge, perspectives, working methods and expertise. In addition, these interdisciplinary research collaborations are as varied as the issues they deal with:

- Interdisciplinary teams differ in size, composition, organization and location.
- They have various objectives, ranging from "fundamental" scientific discoveries to the development of applied technologies.
- Some of their objectives are "restricted", local and informal; others are "broad", transnational and carefully structured.

The lessons that can be learned from interdisciplinary research, as well as the applications of these lessons, often depend on the context in which this research is conducted.

Despite these preliminary remarks, and even though these issues have been seriously taken into account over the past decade, it is clear that interdisciplinary research is generally difficult to sustain and maintain for a variety of reasons:

- Existing funding mechanisms are still, despite recent awareness, most often aligned with disciplinary research.
- In a context of budgetary restrictions, educational and research institutions "naturally" tend to protect their activities considered "essential", first and foremost disciplinary research, which has the effect of inducing significant fluctuations in support attributed to interdisciplinary research.
- Interdisciplinary research is often initiated by supporting pilot projects that are often difficult to prolong into ambitious projects requiring significant long-term resources.
- Funding mechanisms, whether national or European, are not always suitable for interdisciplinary research. Indeed, interdisciplinary research generally involves significant risk and funding agencies may be reluctant to take risks. Moreover, even if the incentives for

interdisciplinarity appear in the recommendations of the calls for projects, national or European funding often favours individual projects at the expense of group projects, and the amounts of fundings to interdisciplinary projects are often modest and attributed for short periods.

- The "standard" modalities of peer review processes make it difficult to evaluate projects that go beyond the disciplinary boundaries of experts or programs.

Nevertheless, as interdisciplinary research is often focused on broader issues than those of purely disciplinary approaches, it can attract funds from other sources. For-profit corporations, venture capitalists and philanthropists may be motivated to invest in interdisciplinary research. Thus, in many cases, the private sector, because it is more used to taking risks and because it sees the commercial value of some applied interdisciplinary research, is more inclined than the public sector to support interdisciplinary research. However, a potential disadvantage of private funding is that it may be so application-oriented that it is likely to divert higher education and research institutions from their educational and research missions.

Two conclusions can be drawn on the basis of these first observations. Firstly, it can be sustained that support for interdisciplinary approaches in research could enrich and enhance the relevance of our research, and make institutions, researchers and understanding of disciplinary approaches even stronger. Indeed, while "traditional" academic disciplines cut out particular areas of knowledge and aim to understand these characteristics as deeply as possible, interdisciplinary research focuses on understanding how these disciplinary understandings can be merged, expanded, and transcended. Interdisciplinary research will continue to require concepts and methods elaborated and developed by disciplinary research, but it will incorporate this knowledge to create new connections between disciplines and new explanations of complex phenomena. Research institutions could place themselves in a perspective where the disciplinary and interdisciplinary approaches will have to be treated in a complementary and inseparable way. Secondly, large multidisciplinary research university concerned to be involved in societal challenges, to understand the challenges of tomorrow in all their dimensions, to be innovative and creative, and to open up to society, must acquire modes of organization and devices targeting means and spaces promoting interdisciplinary approaches in order to introduce flexibility, "risk-taking", freedom and creativity in its practices, out of "routines" and academic constraints.

Interdisciplinarity requires a transition or a change in the way researchers work as well as an institutional framework and methods adapted to this transition. Thanks to the temporary meeting of researchers from different disciplines, institutional framework and methods must offer opportunities for interdisciplinary discussions and collaborations. It has to link Interdisciplinarity, structurally anchored in the identity of the institution, to the flexibility of content and promote different types of Interdisciplinarity:

- **"Free" forms of Interdisciplinarity** favouring exchanges, cross-reflections and reflexivity from different approaches and helping to identify and methodically define relevant areas or objects of research.
- **"Narrowed" Interdisciplinarity**, where epistemic intersections between different disciplinary approaches emerge, and participation in an interdisciplinary research team can have a decisive initial impact through which ongoing collaboration across borders can develop. These narrower forms of Interdisciplinarity can lead to the emergence of new research topics within the university likely to become permanent in major joint projects or in research laboratories as well as in disciplinary institutes.

In this perspective, adapted institutional framework and methods can serve as incubator for new ideas or new areas of interest and leverage / accelerator for emerging projects by favouring an interdisciplinary environment in which research work is conducted on issues that have not yet found their discipline. It must provide researchers or research groups with appropriate time, resources, methods, services and workspaces for THINKING science and DOING science DIFFERENTLY.

Disciplinary structuring: a virtuous construction but not devoid of perverse effects

Before developing on interdisciplinarity, it is necessary to make some reminders about the notion of scientific discipline. A passage through etymology is useful. If its Latin origin refers to "the action of learning" this term has taken multiple acceptances in history. Let us remember, then, that in the Middle Ages discipline referred to a small whip of cords or small chains used by certain religious to flog themselves for the purpose of

mortification of penance or self-criticism, or to chastise those who were under their control. Thus, if we develop this etymology for the needs of our subject, discipline could be a means of flogging one who ventures into the realm of ideas that the specialist considers his property.

This definition has evolved. In science, the notion of discipline refers to a sort of taxonomy established within scientific knowledge, attempting to respond to the large diversity of all the fields they cover. In fact, this taxonomy ultimately establishes an organization, a segmentation and a specialization of work. It establishes categories, tends inexorably to mask the continuum of objects that treat the disciplines.

Thus, even if it is inserted in a vast whole, the assertion and the constitution of a scientific discipline, partly because of the games of actors which aim to create a space of powers by legitimizing their actions by a process of "Institutionalization", tends to the delimitation of its borders and beyond to its empowerment. In return, this process is reinforced by the language each discipline develops, the techniques it develops and uses, its theories and laws. The organization of sciences in disciplines, as we practice it today, is rather recent. It began its crystallization in the 19th century with the creation of modern universities and was considerably strengthened in the 20th century with the tremendous development of research. Disciplines therefore have a history with their birth, development, evolution, adaptation, institutionalization and, where appropriate, their exhaustion, decay and collapse. This story fits in, and shapes that of universities, which itself is part of that of the society. There is certainly a reason why the study of scientific disciplines is at the heart of the sociology of science.

It would be ridiculous to deny that the development of scientific disciplines, by operating area of competence that would otherwise become inconsistent and unformed, by building relevant research objects, was particularly fruitful. The disciplinary organization of science has essential virtues. Each discipline provides a conceptual frame of reference, defining categories, establishing modes of reasoning and analysis procedures to discuss explanations of the world. Each conceptual framework is endowed with a methodology that includes tools of description and testing to construct the research object, to break it down, to make distinctions or reconciliations, to reveal the mechanisms of 'a phenomenon, to present the data and the results, to give an interpretation…

Nevertheless, we must be aware that rise of scientific disciplines and their empowerment carries the risk, reinforced by the disciplinary institution, of the hyper-specialization, of a "reification" of the object of research that each one approaches, breaks its links of solidarity with other objects treated by other disciplines, thus losing sight of the fact that it is built. It would be wrong not to be aware that the establishment of disciplinary boundaries leads to the development of languages and concepts that are certainly fertile but which, according to a process of "speciation", is likely to isolate the disciplines of others, to break down the objects of research and to mask the problems which overlap them.

Interdisciplinarity in science: an approach likely to produce paradigmatic effects

It therefore appears that, while scientific disciplines must continue to develop, it is necessary to work to foster the development of a spirit of openness that is not always spontaneous and often held back by organizations. History has shown us that a "new look", which is not aware of the obstacles that an existing theory places before the development of a new vision, can sometimes be wrongly, but sometimes rightly, make a significant step towards this vision.

Charles Darwin is an emblematic example illustrating this observation. Has pointed out by Lewis Mumford, Darwin had escaped from this unilateral professional specialization that is fatal to a full understanding of organic phenomena. The amateurism of Darwin's preparation proved admirable. As a naturalist on the Beagle, he had no specialized university training, and even as a biologist he had no prior education, except as a passionate animal researcher and beetle collector, or fixation and academic inhibition. Nothing prevented the awakening of Darwin at every manifestation of the living environment. If we add to this the inspiration from the reading of empirist philosophers, that of economist Thomas Malthus and geologist Charles Lyell, whose Principles of Geology was his bedside book on the Beagle, and we see in a single man the conditions of the emergence of a theory which upset the sciences, was decisive in their ability to free themselves from dogmas and beliefs and, here is the essential, profoundly transformed our vision of the Man.

Alfred Wegener, first an astronomer, then a climatologist, then a geologist, then a meteorologist, whose passion for the polar regions cost him his life, is another example. History reports that, inspired by the spectacle of the dislocation of sea ice, it is by looking naively at the map of the South Atlantic that he noticed

that the contours of the coasts of West Africa and Brazil s 'adjusted to each other. It is excited by this trivial observation that it was "sufficient" to note the similarities of fauna and flora, fossils and current, on both sides of the Atlantic. He had then “just” to combine approaches relating to geodesy, geophysics, structural geology, and palaeontology to elaborate, in 1912, the theory of continental drift, however long refused by specialists because "theoretically impossible", and which was only admitted forty years later, after the discovery of plate tectonics.
So, sometimes, when we do not find a solution in a discipline, the solution can come from outside. Descartes had already warned us in the 17th century by addressing this advice to us in the “Rules for the direction of the mind”: "If anyone seriously wants to seek the truth, he must not do the choice of a particular science; they are all united to one another and depend on each other. Let him only think of increasing the natural light of his reason.”

We must admit that the cases of Charles Darwin and Alfred Wegener are exceptional. But they illustrate the fact that the history of science is not only that of the constitution of disciplines. It is also that of breaks in disciplinary boundaries, overflowing of one discipline onto another, of circulations of concepts, of formations of hybrid disciplines that may end up becoming autonomous. It is also the story of the formation of complexes where different disciplines will aggregate and clump around hybrid objects. So, while the "official" story of science, as it is told today, is that of discipline, another related and inseparable story is that of multi-inter-trans-disciplinarities. It is indeed exceptional that such phenomena of rupture, circulation, hybridization, encroachment, aggregation and agglutination occur or are initiated by a single individual. The examples that come to mind spontaneously begin to date: Darwin, Wegener, Descartes, Pascal, Aristotle ... It is possible that with the tremendous development of the search for such miracles no longer occur. That's why we collectively need to do science differently.

What is called the "biological revolution" of the 1950s, born of overlapping, contacts, transfers between disciplines at the interfaces of physics, chemistry, and biology, illustrates this point. Physicists like Erwin Schrödinger, or later physicochemists like Ilya Prigogine, have projected on the biological organism the problems of physical organization. It was after Erwin Schrödinger that other researchers, initially marginal in their posture, tried to, and then managed to solve the organization of genetic heritage from the chemical properties of DNA. Cell biology, molecular biology, which had no disciplinary status in the fifties, were born of these "illegitimate" encounters and finally gained their status in the sixties, before becoming autonomous, tending to close on themselves. Certain notions, specific to certain disciplines, are therefore likely to circulate, to cross disciplinary boundaries and thus to migrate, to go against the main drift. While the *doxa* will recall that a notion has relevance only in the disciplinary field where it was born, certain notions are likely to fertilize a new disciplinary field if we allow its migration, its rooting, even if it is at the price of an original counter sense. Has it was pointed out by Edgar Morin, the notion of information is exemplary of this process that can transform the sciences in depth. Coming from social practice, it acquires a new and very precise scientific sense in Claude Shannon's theory, before migrating to the territory of biology to implant itself in the gene. It is there that it mutates by associating itself with the notion of code resulting from the legal sciences, to become “biologized” in the notion of genetic code. Those who practice molecular biology must be aware of this history and process according to which a central notion for the intelligibility of their discipline and, that is the essential, of the organization of the living, is inherited from anthropology and sociology.

Conversely, however, it is important to be aware of the potentially harmful, even disastrous misinterpretations made during certain migrations. Once more, the most emblematic illustration of this phenomenon comes from the theory of evolution by natural selection elaborated by Charles Darwin and Alfred Russel Wallace, which, transposed out of his field, led to the reinforcement of Herbert Spencer’s conceptions of evolution, inspirer of what was (badly) later called Social Darwinism, or served as a so-called scientific base for Nazism which was defined as an "applied biology". Finally, there is much more to be said, beyond the phenomena of disciplinary fertilization by migration of notions, on the phenomena of fertilization by migration of objects, concepts, or disciplinary cognitive schemes. One can think here particularly of the prehistory and the study of hominization, moving the objects of the anatomy towards the techniques, the ecology, the genetics, the ethology, the psychology, the mythology, the sociology, the physics, the arts ... We can also think of the environmental sciences where a systemic organizing concept such as that of ecosystem goes from geography to geology, bacteriology, zoology, botany ... We can also think about the study of the cosmos, which migrates the cognitive schemes to connect various disciplinary knowledge in order to treat the universe and its history and to introduce into the heart of the sciences problems that seemed to be related only to philosophical speculation. Finally, we can think of the convergences that have taken place between mathematicians and engineering specialists to create self-governing machines and lead to the emergence of cybernetics, computer science and

artificial intelligence. It is therefore time to become fully aware of this aspect of the sciences in motion, by breaking the isolation of the disciplines, by the step aside, by the circulation of notions, objects, concepts and cognitive schemes, and create the conditions from the emergence of new cognitive schemes, new paradigms and new explanatory hypotheses, to constitute organizing conceptions that make it possible to articulate disciplinary domains.

The structuring of the disciplines, the paradigms by which they operate, which direct the minds by instituting the sovereign concepts and their logical relations and by governing, often unconsciously, the scientific conceptions and theories, are justified and fertile on the condition that their fields of vision make it possible to conceive the existence of relations and solidarities; if they do not obscure the global realities and stop fragmenting the notion of Man between different biological disciplines or tight human sciences: psyche here and there, the brain there, the body elsewhere, genes everywhere, history and culture we do not know where.
Here are the observation and the diagnosis that should lead the University to constitute real research communities likely to renew existing networks, to build bridges between disciplines, as between the university and its environment, while questioning our ways of working to create a new style of intellectual relations between researchers, teachers, students, artists, designers, entrepreneurs, policy makers, citizens. A new style of relationships that will lead everyone to let themselves be jostled, provoked, brought out of their comfort zone and thus provoke a fertile confrontation to understanding, innovation and creation. This is because no innovative response to the contemporary challenges faced by human societies, territories, businesses or public organizations has emerged from a single academic discipline.

Support interdisciplinarity, creativity and innovation in science: an approach that requires method and know-how

As pointed out earlier in this chapter with the examples of Charles Darwin or Alfred Wegener, the history of science shows us that an interdisciplinary approach can be operated by a single person capable of mastering, at a high level, the knowledge and methods of several disciplines, and lead to major breakthroughs. Nowadays, with the tremendous development of the sciences, it is unlikely that such "miracles" could happen again, except in the event that the issue addressed is not too complex. It becomes impossible to cover large areas as an "expert" because of the considerable amount of knowledge generated by each discipline, the speed at which new knowledge is produced and their fragmentation into sub-disciplines. Moreover, by nature, "problems" generally go beyond the domain of a single discipline. Their analysis, study and resolution require close and coordinated cooperation between competencies specific to several disciplines. This cooperation is the prerequisite for a good understanding of the problem addressed, in a relevant systemic framework. It allows to establish a dialogue between the different mobilized disciplines, a better understanding of the concepts, knowledge and methods brought by each one, to have a global vision of the context as well as, sometimes, a better understanding by the specialist himself of his discipline and the field it is able to cover.
In this context, the interdisciplinary approach therefore has two major interests:

- **complementarity**: to the extent that, in the context of a complex problem, no discipline can solve everything or explain alone, the interactive cooperation of several disciplines brings a better light;
- **creativity and innovation**: insofar as interactive cooperation between disciplines pushes the members of the interdisciplinary team out of their comfort zone, they face the need to produce new, original explanations and, where appropriate, methodological innovations.

Ultimately, this interactive cooperation creates the conditions and the scenery that enable researchers to give themselves an overall picture of the problem, allows them to broaden their understanding, adapt their own research methods, concepts and techniques, their skills to this enlargement. From there, they are able to take a new look at the biases and limits of their own discipline, to extend their knowledge and perspectives, to be creative and innovative.

Studies in this area show that, in order to activate an interdisciplinary approach, multidisciplinary collectives need shared objectives, with a leader able to constantly renew and reorient the team. Teams need to be supported by organizations, to have human and financial resources, to have confidence and autonomy. They also show that cooperation, sharing of knowledge, diversity, etc., are very complex processes and that it is not enough to have good and motivated members, as well as an organization that supports, to get results. It is therefore necessary to have in-depth knowledge of the levers and the brakes - individual, coming from the teams or the organization - to put in place actions of promotion and stimulation of the creativity and the

innovation to support and accompany interdisciplinary and international research teams. The training of researchers to work together is therefore a necessity. It can be conceived as an "awareness" of teamwork, knowledge of the most significant processes, their risks and benefits. Teams "activated" after a long preparatory work will therefore need "subtle" support and follow-up from a team process expert, who may be a member of the team trained for this role or a referent working within the Institution. It will therefore not be enough to activate individuals towards an interdisciplinary research objective. It will also be necessary to support the training of the teams, to accompany the definition of the objectives, if necessary the conception of the projects, and the organization of the collaborative work. It will be necessary to equip the teams with all the necessary tools, to train them to work together, to support them with expert guides, to help them overcome all the difficulties, to erase the processes likely to curb them and to favour those who value and release the creativity and 'innovation

The conditions required for successful interdisciplinarity

Conditions related to the team's operation: install a team climate

The success of an interdisciplinary team, its creativity, depends on the realization of a fundamental condition: the transformation of a multidisciplinary collective into an interdisciplinary team that passes by the development of a "team climate". Team climate can be defined as the shared perception of the atmosphere created by practices, procedures, recognition within the team. "Team climate" captures the team's shared work experience, formed by team interaction models, and the implicit or explicit message that these models convey from what is seen as appropriate and inappropriate, desirable and undesirable by the team ". The concept of "climate" captures how we do things and how we believe things must be done. In research on team innovation, climate is probably one of the most developed perspectives. The proposed team climate model for innovation considers three main elements:

- **support for innovation** from the leader;
- **shared goals / visions**;
- **task orientation / climate for excellence and participatory security** - the feeling that everyone can freely contribute and participate with their ideas.

This model has been tested and validated. It highlights factors that are prerequisites for creating a team climate and that can create a favourable or unfavourable context for creativity and innovation. This research has shown that some factors such as clarity of leadership, creative personality of members, support of the organization for innovation, empowerment climate of organization, design of work at team level, organizational citizenship behaviours, team effectiveness, trust in the leader and other members, affect the team climate and, therefore, the team's ability to innovate.

• Balance tensions and antagonisms

Ed Hackett, a sociologist at Arizona State University, a specialist in the social organization of science, proposed a theoretical perspective on creating an interdisciplinary structure. He points out that the culture of science is in many ways a culture of contradictions. Rather than forging compromises between extremes, creativity and success often flourish in the presence of antagonisms. Some of these tensions include:

- Originality ↔ Tradition

- Selflessness ↔Passion

- Cooperation ↔ Competition

- Closing ↔ Opening

- Sharing ↔ Secret

- Distinctiveness ↔ Sense of belonging

- Commitment ↔ Independence

- Autonomy ↔ Responsibility

- Democracy ↔ Autocracy

From this perspective, interdisciplinary research requires making choices about how to balance these tensions that may differ from established disciplinary practices. Achieving this new balance can be tricky. Disciplines often have distinct cultures and different ways of doing science. A descriptive discipline, such as palaeontology, applies research standards different from those of a discipline based on experimentation or theory. Publishing

practices, data sharing traditions, and even certain subtleties related to ethics or scientific standards may vary from one area to another.

• Install trust

The installation of trust is particularly important in an interdisciplinary team. Collaboration can be risky or threatening at the personal and institutional level. Participants must be willing to sacrifice some of their independence and autonomy for interdependence and group identity. They must be able to give up some of their ego and be certain that others will do the same to achieve common goals. Engaging in planning processes and establishing policies that define expectations and responsibilities can build trust. This procedural trust can, in turn, support self-confidence. Procedural confidence and self-confidence are thus likely to favour the establishment of strong individual relationships.

• Manage cooperation and conflicts

Other areas that have proven useful from a climate perspective are cooperation and conflict. Sharing objectives in the team's work is an essential foundation for producing the team's effectiveness, performance and innovation. More complex seem to be the roles of cooperation and conflict that would have negative or positive effects depending on the typology and size of the conflict. The analysis of the work conducted in this area shows that the organization of the team, for its work to be successful, requires that certain conditions are met:

- The first is to **agree *a priori* on shared objectives**, clearly formulated involving all disciplines instrumentalising none of them. These objectives must be formulated in such a way that the work of the whole team converges, define and guide individual contributions. Intense collective work must be conducted in order to clarify the terms of reference that frame the problematic, place the starting point of the interdisciplinary work, draw the backdrop for the conduct of the project, frame the subject treated, position the members of the collective according to the results expected from the team.
- The second, particularly delicate, is **"to optimize" the balance between individual work and collective work**. The conduct of interdisciplinary work does not require the participation of each member of the team in all activities. The contributions of each discipline, the individual skills, the distribution of the tasks must be precisely organized, programmed throughout the project and adapted if necessary according to its progress so that the interdisciplinary team produces an effective work.
- The third falls within **the competence of each member of the team**. Creating an interdisciplinary culture requires making decisions about the types of people to be recruited into a program. Researchers have diverse skills and very different reasons for doing interdisciplinary research. One approach is to attract what might be called the "best athlete" - researchers who have demonstrated "productivity" in outstanding research, whether or not they have experience in interdisciplinarity. Another approach is to attract researchers who have already demonstrated effectiveness in an interdisciplinary experiment or who have a strong appetence for this approach. In keeping with the interdisciplinary "concept" of culture of contradictions discussed above, program managers may choose to enlist both types of individuals in order to create productive tension between their work styles. In any case, the ability of an interdisciplinary team to analyse complex subjects, its competence as a collective, require that of each of its members. Each one must be able, by his competence and his openness to the others, to feed the collective reflection, to produce a detailed and relevant analysis of the information which he holds and to transmit it. The deficiency of a member, whether it relates to a lack of control of the concepts, the knowledge, the methods, the capacity to articulate his point of view, is likely to introduce errors of interpretations, a weakening of the ability to gather and synthesize valid and relevant information and data, which in turn can distort the judgment of the entire collective and lead to false leads. A marked imbalance in the skills of members of the collective may produce adverse effects such as:
    - the predominance of the perspective of one of the disciplines to the detriment of others;
    - removal of the project from the most competent members who may feel discouraged and withdraw to a passive attitude;
    - a narrowing of the project by the capacity of the deficient member, ruining the added value of the interdisciplinary approach.

- The fourth is **the ability of each member to understand the conceptual model specific to each discipline** mobilized around the project. Each member of the interdisciplinary collective will therefore:
    - understand, recognize and integrate the contribution of other disciplines and the potential of their possible contribution to the current study;
    - understand the specific language - "jargon" - of their colleagues in order to be able to communicate with them;
    - perceive differences, similarities, possible areas of recovery with their own discipline.

- The fifth is **the ability to manage conflicts**, inevitable or even desirable, within the interdisciplinary team. This capacity must be integrated from the initial design phase of the project, which must ensure that the outputs and inputs of each discipline are comparable and complementary. The organization of the collective work must allow each member / discipline to value its contributions in a language understandable by all its members, and to integrate them into the collective result.
  Conflicts between disciplinary visions have two main sources: conceptual and methodological incompatibilities, on the one hand; linguistic misunderstandings, on the other hand. They are inevitable within an interdisciplinary collective. In a sense, they are even desirable as the added value of the interdisciplinary approach is often the resolution of these conflicts. Indeed, the ability to solve these conflicts requires an epistemological work aimed at converging on the modalities of integration of the concepts and methods of each discipline, to analyse the comparative advantages, avoiding to lock oneself into sterile arguments on the questions by constantly returning to the object of the study and the co-opted terms of reference.
- The sixth is **the ability of the collective to develop a coherent and common interdisciplinary model, according to the needs of the project**, placing at its centre the confrontation of the disciplinary contributions and the interests expressed by each member for the problematic. To this end, the collective work should allow the team and each member to identify and agree on:
    - its data and information needs;
    - the concepts best suited to the analysis of the problem;
    - the tools best suited to collecting specific information;
    - the contribution of specialists in each discipline to the collection and interpretation of information;
    - the specific procedure able to involve the interest groups in the process.

Conditions relating to persons

Nevertheless, it should not be overlooked that the group's ability to manage to build trust, balance tensions, manage conflicts, depends on many people-related conditions. The interdisciplinary team aims to solve problems and its ability to do so largely depends on the learning of joint work by each of its members. This learning is largely based on the team's ability to take advantage of the diversity of its members in terms of experimentation, evaluation and capitalization, for better results. Everyone must have the will and the ability to work together and to give up a dominant position. From this point of view, five points must be taken into account with the greatest attention:

- **The opening of team members to diversity**. The diversity of points of view is the particularity of interdisciplinary teams. An interdisciplinary team must look at the problems from different angles to find the best solutions. Without it, it can be locked in a "group thinking" that is to say the same way of seeing things, to have the same opinions and to make unanimous decisions that can in fact be summarized conventional decisions. If the team wants to remain innovative, each of its members must accept this challenge in their way of thinking. This requires an open mind and a positive way to respond to conflict.
- **The ability of each member to be part of a process of mutual support**. By encouraging teammates, each team member improves their own performance and thus the team's performance. Mutual support can be manifested by:
    - assistance when needed;
    - a sharing of resources;
    - constructive criticism of ideas;
    - a permanent reminder of the objectives to be achieved.

- **A procedure for evaluating learning**. Learning is by nature an iterative process. It requires regular feedback. In an interdisciplinary team, this feedback must be provided by each member. For this, the team needs a procedure to review its processes.
- **Social skills**. In addition to their disciplinary expertise and recognition of the knowledge and skills of others, team members must be able to work with each other. This requires basic skills in managing one's expression, emotions and those of others. These basic skills are the foundation of all teamwork and require self-awareness and self-discipline. If team members cannot adjust their behaviour to the needs of others, they may hinder participation and reduce the effectiveness of teamwork.
- **The recognition of interdependence in the team**. A basic condition for team success is that each member of the team recognizes that their personal success depends on that of their teammates. This interdependence is linked to the following points:
    - roles: team members depend on each other to perform their tasks;
    - resources: logistical means, time, sources of information are shared by all;
    - objectives: The objectives of the study are common to all members of the team and will be judged according to their achievement.

The organization of the multidisciplinary collective to operate interdisciplinarity

The general agreement

General agreement on the purpose of the research is a basic requirement for future interdisciplinary teamwork. The multidisciplinary collective must arrive at a consensus at this general level in order to constitute an interdisciplinary team before attempting to operationalize its research. The terms of reference determine the framework and objectives of the study. Once an agreement has been reached on the research problem, the contributions of each discipline must be made explicit. At this stage, each specialist must present:

- its concepts and their relevance to the ongoing research project;
- the temporal and spatial scales in which its concepts are operational.

The team can then evaluate the differences and complementarities between disciplines and make decisions about their respective comparative advantages, the steps that will make up its interdisciplinary model, the selection of tools and the division of tasks. Once everyone's knowledge has been reviewed, the team must come to an agreement on a common framework. For this, it must decide whether the disciplinary knowledge available to it is sufficient, or if it must resort to concepts or skills from other disciplines. Two points are important during this phase:

- **recognize diversity and resist the temptation of consensus** - two coherent but different concepts are better than one hybrid but incoherent concept;
- **avoid sterile theoretical discussions** and do not hesitate to go to the field and check the validity / feasibility of these concepts.

To preserve the interdisciplinary nature of teamwork, certain conditions are necessary:

- the results of several disciplines must be comparable and complementary.
  The scales at which different specialists work should allow a synthesis of all inputs;
- the disciplinary results must be rendered in a language understandable by all, avoiding "jargon" as much as possible, and be easily integrated into the overall results;
- the degree of information of each specialist should be as much as possible the same, otherwise the collective result risks being biased towards the most informed discipline.

The division of tasks

Divide tasks among disciplines is the biggest challenge of interdisciplinary work. It is necessary at the same time to:

- have a formal agreement of each one on the division of tasks and set the deadlines essential for effective management of the team;
- preserve for all participants a margin of interpretation of this agreement in order to preserve the necessary creative flexibility in the face of changing conditions and opportunities.

The success of the combination of these two imperatives will largely depend on the team's prior formulation of research themes and disciplinary contributions. While a relaxed atmosphere contributes to the dynamism of the team, a permissive attitude can degrade teamwork. The interdisciplinary team must therefore develop a

(written) agreement on the basic rules of working together, to ensure that each of its members participates and contributes to the results as agreed at the beginning of the research. These rules include at least:

- clarification of individual responsibilities, in the collection, analysis and processing of data, and in leadership;
- a schedule providing for the exchange of information and evaluation of contributions;
- a procedure for evaluating individual contributions and decision-making for further operations.

The question of leadership

The distribution of research tasks between specialists presents a risk of drift for some team members. It takes strong intellectual and human resource management leadership to keep the direction. Leadership tmust possess the following qualities:

- the ability to understand others, to respect their own perspectives and to learn from them. For this, the leader of an interdisciplinary team must be able to think outside the limits of his own discipline;
- the ability to synthesize the contributions of the different members and to formulate proposals accessible to all;
- the ability to facilitate the day-to-day work of team members while keeping an overview and an ability to anticipate.

Risk management

Managing risk is another challenge. Interdisciplinary research is almost always risky. Interdisciplinary project leaders, with the support of institutional leaders, must learn to accept "negative" results as well as "positive" results. Balancing positive and negative outcomes is an ongoing challenge. It is important to test ideas quickly so that failure can happen quickly rather than progressively. It is also important to transmit rapidly the negative results to the entire interdisciplinary collective to increase knowledge about what works and what does not work. Finally, the evaluation criteria vary considerably from one discipline to another, the definitions of common terms such as "data", "hypothesis", "survey", etc. can be understood in different ways. It is therefore very important for the team to set evaluation themes and methods of quality control and relevance.

The main challenges to be met as part of the service offer to support and accompany interdisciplinarity

A mission of the Institution is to support and accompany interdisciplinary teams engaged in research projects. Moreover, in keeping with its objective of opening up the academic world to the economic and social world, the Institution will reserve a significant place for "action research" and "participatory research". Research that has the potential to inform decision-making on the part of policy makers, non-governmental organizations, businesses and citizens. Beyond the difficulties to lead the interdisciplinary research, the service offer will have to integrate:

- involvement of actors from the socio-economic world, from citizens, non-academics, to formulate research questions that focus on solutions to social, socio-economic and socio-environmental "problems";
- involvement of actors from the socio-economic world, citizens, non-academics to collect and analyse data;
- ability to advise on policies and institutions that may have an impact on decision-making;
- communicate with a wider audience.

This approach must therefore involve the creation of new interdisciplinary communities:

- often bringing together members who have never collaborated before;
- involving, where appropriate, actors from the socio-economic world who will have to be able to participate "in bursts", to interact only a few times a year and
  in sessions of a few days;
- often having to rely on existing data and knowledge, rather than on original data produced in the laboratory;
- often having to deal with heterogeneous data integration difficulties.

These teams will therefore have different working methods from those commonly practiced in the laboratory and adapted support. In fact, these multidisciplinary collectives, which will have to be organized as interdisciplinary teams, will face complex problems. Therefore, it can result:

- several ways, sometimes incompatible, to see or formulate problems or solutions;
- difficulties in identifying and recruiting the disciplines necessary for the analysis and the treatment of the problem;
- difficulties in developing projects able to satisfy the injunction to be globally relevant and to propose sustainable development solutions;
- difficulties in articulating the spatial and temporal scales of the problems dealt with;
- difficulties in integrating qualitative and quantitative data;
- a high degree of uncertainty related to the quality of the data or their unavailability;
- "philosophical" conflicts linked to the "values" inherent to the problematic dealt with;
- a lack of understanding or respect for the scientific methods of different disciplines that may be considered *a priori* incompatible.

These complex projects involve interdisciplinary approaches led by collectives bringing together members from very diverse backgrounds and requiring strong inter-disciplinary and intersectoral team skills. Issues related to the interdisciplinary method and the conditions for its success, discussed earlier, are particularly sensitive. In addition:

- linguistic / epistemological differences must be overcome in order to reach a common understanding;
- the size of the group (too big / small) can hinder creativity and progress in integration between disciplines;
- too little or too much familiarity between the participants can lead to phenomena of lack of cohesion of the collective or the constitution of "clans";
- differences in power, perceived or real, and / or disciplinary domination within the group can destroy the project;
- a lack of flexibility within the group or the installation of too strong leadership are likely to predetermine the process and the way forward;
- the interdisciplinary and intersectoral diversity of the group is likely to introduce considerable uncertainty about the project's objectives or lead to a lack of shared purpose, inadequate communication and a lack of clarity about the role of each participant.