MOOC Scientific Humanities

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A product of the médialab of Sciences Po

Teaser for the course

Suppose you are a student alerted by a tweet about the latest report by the United Nations body called the IPCC on the speed of "global warming" and that, at a family party, your uncle tells you that you should say "climate change" not "global warming" and that climatology is a scientific discipline thoroughly "polluted" by the "political views" of "the enemies of free enterprise". What do you do? One way is to lose any confidence in the authority of science — or in your uncle's sanity. The other solution is to begin to learn how scientific knowledge is produced and through what sorts of processes it achieves a type of certainty essential for the evolution of political debates. To do so, you will have to dive into an ocean of news, reports, opinions, scientific articles and disputes. But before diving you need some equipment.

Don't panic. This equipment is what the course will provide you with. We are going to offer you the opportunity to utilize a blog in ways that will help you make up your mind about controversial matters. In our view, this is one of the many ways to regain some confidence in the authority of science — and to conclude family parties without punching your uncle in the nose! You have to become well versed in "scientific humanities".

Usually the word "humanities" means the interpretation of the literary and artistic traditions. "Scientific humanities" means the extension of those interpretative skills to the discoveries made by science and to the technical innovations that define a large part of our daily world. It is the only way to overcome what is often called the "two-cultures" divide: science on one side; literature on the other. We need to equip future citizens with the means to be at ease with many issues that straddle the distinctions between science, morality, politics and society. Such interpretative skills are especially important when dealing with ecological issues.

During six sequences, you will learn

a) the basics of the field called "science and technology studies", a vast corpus of literature developed over the last forty years to give a realistic description of knowledge production;

b) how to handle the flood of different opinions about contentious issues and order the various positions by using the tools now available through digital media; and

c) how to comment on those different pieces of news in a more articulated way through a specifically designed blog.

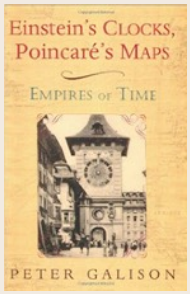
The course is designed for undergraduates but since the topic of scientific humanities is not widely known, it will be of interest for graduates and for the general public as well. Although it does not require a degree in science and technology, it will be of interest to scientists, engineers and physicians who will apprehend their traditional subject matters in a very different light. For those without any advanced knowledge in science, it will be a good occasion to become familiar with what is now an essential part of their culture.

Today, no one can afford the luxury of ignoring how science and society collaborate to mold our common world.

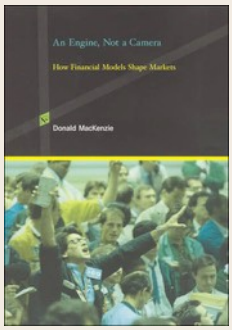
Sequence 1: How to patrol the borderline between science and politics?
Sequence 2: How to find one's way in the scientific literature?
Sequence 3: How to handle technical innovations?
Sequence 4: How to deal with controversies?
Sequence 5: Feedback on blogs done by MOOC students.
Sequence 6: How to understand the shifting nature of the natural world?
Sequence 7: How to become a citizen in the public life of science and technology?

What are Scientific Humanities?

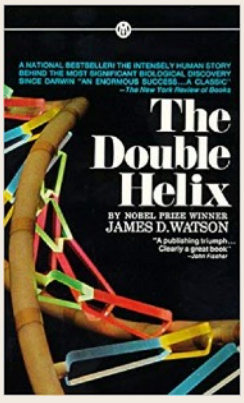
Since this is not a well-bounded field, you will likely come to understand what it is only at the end of the class! In the meantime it is probably best to define it by a few examples. I have chosen them to give you an idea of the range of topics we are going to deal with.



Suppose you have always had trouble understanding the importance of Einstein's relativity theory, and that you learn, by reading a marvelous book on his early days as a patent officer in Bern, Switzerland, that the Patent Office had to review dozens of "time machine" inventions designed to coordinate the clocks of the many railway companies sprouting up throughout Europe. Suddenly, everything falls into place: what had appeared as a terribly abstract argument was given flesh and blood. Even abstractions need a material ecosystem. **This is the scientific humanities**. (Peter Galison. *Einstein's Clocks, Poincarés's Maps*. New York: Norton and Company, 2003.)



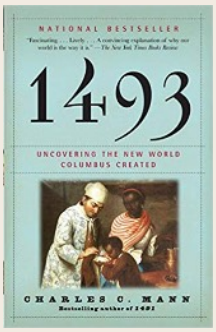
Suppose your parents have lost their house in the recent financial crisis and that you realize, by reading a book on the Black-Scholes equation for pricing "futures" that this equation, before being embedded into computer models and banking organizations, was manufactured by specific people in a highly specific situation. That far from being a "camera" recording a state of affairs, it has been a powerful "engine" for allowing bankers to take even more risks than they would have taken without this tiny piece of mathematics. Suddenly, what had seemed to you the inevitable thrust of a free market became one of the highly contingent products of a link between mathematics and banking that you might learn to resist. **This is the scientific humanities**. (Donald MacKenzie. *An Engine, Not a Camera: Finance Theory and the Making of Markets*. Cambridge, Mass: MIT Press, 2006.)



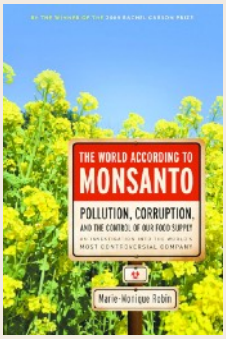
Suppose that after a class on molecular biology your teacher had the good sense to direct you to the reading of James Watson's The Double Helix: what a delight to read from the mouth of the discoverer himself how this most important discovery had been made. Even if the story is a bit self-serving, even if it is not fully accurate historically, suddenly what had been for you a result to learn for an exam ("A pairs with T; G pairs with C"), became one episode of an adventure, an adventure that continues today and that you might want to pursue yourself. The beautiful excitement of science and the sheer beauty of the double helix itself strike you to the full. **This is the scientific humanities**. (James Watson. *The Double Helix*. New York: Paperback Mentor Book, 1968.)

Suppose that you try building a small appliance using your own hands and the material around you, let's say a vacuum cleaner or an electric toaster. And that you realize that you need months of travel, a lot of learning, much sweat and a great deal of money to end up with a horrible kludge that works for a few second before exploding! Then you would have realized that what an "object" needs to exist as a reliable and inexpensive appliance is a whole ecosystem of industries, engineers, marketers and stores. **This is the scientific humanities**. (Thomas Thwaites. *The Toaster Project - or a Heroic Attempt to Build a Simple Electric Appliance from Scratch*. New York: Princeton Architectural Press, 2011.)

Suppose that you decide to eat only "local" food and that you realize, reading a book on the history of the spread and displacement of plants and people, that this enterprise has been made extraordinarily difficult since at least 1492. That the very notion of "native" plants (as well as that of "native" people) depends on the time frame you choose, and that if you begin to take a larger unit of time what you observe is a frenzied agitation of all the components of what had appeared, before you started this search, as a stable and immutable landscape. **This is the scientific humanities**. (Charles C. Mann. *1493. Uncovering the New World Columbus Created*. New York: Vintage Books, 2011.)



Suppose you are a young Indian student and that you worry about the controversies raging in your local press about GMO modified eggplant, rice or cotton that your parents want to grow in their fields and that you feel, for some reason, should be resisted. It is crucially important to measure the relations of power between the various protagonists so that you know in what sort of science and politics imbroglio you are going to engage. How interesting to watch the documentary (even it is fairly one-sided) and read the book of a journalist who has done an inquiry on the power of Monsanto, the arch villain of so many controversies over the future of agriculture and food. **This is the scientific humanities**. (Marie-Monique Robin. *The World According to Monsanto. Pollution, Corruption and the Control of Our Food Supply*. [Translated by Georges Holoch]. New York: The New Press, 2012.)



Okay enough examples! Now you have to see for yourself, and if you want to have a good overview of the field of science studies out of which this course has grown, it is probably best that you get access to a reader. (Mario Biagioli, ed. *The Science Studies Reader*. London: Routledge, 1999.)

INTRO—SEQUENCE 1: HOW TO PATROL THE BORDERLINE BETWEEN SCIENCE AND POLITICS?

There exist two situations for which this course is of no use whatsoever. Situation one: you follow people who go on doing their business without ever using a piece of technology, without ever hesitating to think about the solidity of a piece of information that they need to make up their mind, without ever having to be confronted with experts who know more than they do about some state of affairs. Not a very realistic situation, I agree. Situation two: you encounter a piece of information about a state of affairs that has not been produced by anybody but that has come directly to you without any trace of its origin, no date, no indication of place, no trademark of any sort, just sitting there, in front of you, indisputable. Although it is not as commonly recognized, I think you will easily agree that such a situation is just as unrealistic as the first.

If you look around, you will find that most daily encounters require that you use, at some point, a piece of technology, that you stop to think about the solidity of some piece of information and that you meet experts. And you will notice that those experts, who claim that they know more than you, will, when they are challenged, direct your attention to where, when and how this piece of information has been produced. In other words, if we want to be a bit realistic as to how we go about managing our daily business, we have to recognize: one, that we are constantly dealing with techniques and very often have to rely on some expert knowledge; and, two, that this knowledge depends on people and places that appear to play a crucial role in its solidity, robustness and accuracy.

You find this obvious, even trite? Well maybe so, but you will soon realize that it is very difficult to offer a realistic description of such a trivial state of affairs. Why? Because we seem to suffer from a division of intellectual labor: if you have learned history, social sciences, literature, law, art or any branch of what is called "the humanities", I am sure you have learned a lot of things, but not necessarily about how technology and science have interfered in all those various fields; conversely, if you have taken classes or degrees in engineering, computers, natural sciences or various applied trades, I am not sure that you will have learned a lot about when, where and by whom those elements of knowledge have been produced and what relations they entertain with history, literature, art, politics or social sciences.

If you are a doctor, how many classes on the history of medicine did you get? If you are a lawyer, how many classes were you offered on the laws of physics? If you are an engineer how much have you read in the social history of technology? If you are an accountant, what have you learned about the early philosophy of your discipline?

Whichever field you come from, chances are that you have realized that there exists a divide between those coming from "the letters" and those who come "from

the sciences". And not only a divide, but often alas, some form of condescendence, even of spite against those of the other side: you might have been treated as a "illiterate nerd" by some bright literary scholar who, in turn, might have been treated as a "romantic prick" by some serious fellow from the mathematics department. If you have never encountered such reactions and never noticed this divide, you are very lucky and you don't need this course!

Those who need it are those who wish to bridge the gap between the two sides (what are often called "the two cultures") and to learn how to provide a more realistic description of our daily encounters with technology and science.

Such a course is not a substitute for the many classes in the humanities, nor it is a substitute for classes in the natural and the social sciences. Take as many of those as you can get. What we are offering you here is a highly specialized course on how to deal with nothing else but the interface between those various trades. And of course, the more you master them, the better.

One of the difficulties you are going to face is that this highly focused question — how are science and technology connected with the rest of our daily life? — will lead you, step by step, to many different sites you would have never visited without asking it. So, even though it is very specific question, it is also a very large one since, as you will soon painfully notice, there are very few situations that we will not have to redescribe in order: one, to underline the role of science and technology in molding them; and, two, to foreground the role of people and society in molding, in turn, those results of science and technology. The material is everywhere, what is missing is how to handle it.

Don't be afraid, we are going to help you in this double movement: how to focus your attention on the interface — it is often described under the label "STS" for "Science and Technology Studies" — and how to enlarge your vision by asking you to follow a very practical procedure. The procedure will provide the empirical material that you will have to deal with according to the concepts we will also provide you with.

Let me start with the most important, namely the practical procedure. We are going to ask you to maintain a blog devoted to the class. This blog will bear on a small segment of your life: what you have noticed between the beginning of the class and its end that is linked to the questions of the class, much as you would do if you had a private notebook. We are not asking you to learn about the whole history of science, the philosophy of technology, the foundation of physics or the nature of evolutionary theory. No, we just want you to record, as accurately as possible, what is happening around you that provides some information about the ways science and technology intersect with the many events of your daily life. How to do this practically is explained in chunk xx. Be assured that you are not going to lack material: after a few weeks, your blog will overflow with too many posts!

Now, don't think it is too easy either. Maintaining a blog will simply allow you to gather the primary material. The next procedure spells out what to do with this material. As I said, what we are going to teach you will oblige you to constantly cross the often very deep divide between "the two cultures", those of the "humanities" and those of "science". For such a crisscrossing there is unfortunately no widely shared set of expert methods. We will often have to fight against common sense as well as deeply entrenched reactions. This is what makes this course challenging, sometimes controversial, but on the whole very exciting!

Fortunately we will rely on a large body of work coming from the STS field. For forty years now, historians, sociologists, economists, psychologists, archeologists, anthropologists, political scientists, administrators and many concerned scientists together with some philosophers, have offered many alternative descriptions of how science and technology are produced. Collectively, they have offered a very different view of the many ways in which the two cultures are related. So, we are not going to ask you to reinvent the wheel. In each sequence, you will be directed to some of the best examples of this literature.

However, this is not a course in STS or what is often called "science studies" either. This course offers a primer that should later help you to read this literature and to learn more about this field. This is why I prefer to use the word "scientific humanities". What we need to teach you is a set of interpretative skills — the main resource of the humanities — that have a bearing on science and technology — this is what means here the adjective "scientific". It does not mean that we wish to render the fields of humanities more "scientific" in the sense of being entirely explained by the natural sciences, but, on the contrary, to help you develop a set of systematic, rigorous, methodical critical tools to handle the many instances where science and technology have impacted your life and the life of those you will follow through your blog.

This first sequence will show you how to get started. First, I will give you two historical examples so as to highlight the two main concepts we need as we go along, that of translation and composition. Then, we will explain how to design your blog posts and will provide you with examples so that you see how it works. Nothing really complicated, even though it requires a good deal of attention and a readiness on your part to suspend many clichés about science as well as about society. My hope is that you gain a new respect for the ways science and society really work.

INTRO—SEQUENCE 2: HOW TO FIND ONE'S WAY IN THE SCIENTIFIC LITERATURE

I am sure that you have heard about the great French philosopher René Descartes who lived in the 17 th century. One of his sayings has become so famous that it has been turned into an icon of modern philosophy: "I think, therefore I am" — in Latin (the language of scholarship at the time, just like English is today): "cogito, ergo sum".

Well, there is an amusing as well as intriguing paradox in this sentence, because Descartes lived just at the time when a scientific community began to get organized throughout the whole of Europe (by the way the word "scientist" did not exist at the time, they called themselves "natural philosophers"). So when he says: "I think therefore I know for certain that I am", he is also implying something exactly opposite: "We, the new emerging community of philosophers and experimenters, are thinking collectively, trying to ascertain, through experiments, a whole set of new claims about what the world is made up of". Hence the enigmatic motto we have chosen for this class: "*cogitamus ergo civitas sumus*". Not "I think", but "we think" and not "therefore I am", but "therefore we form a group of citizens sharing more or less the same values and having more or less the same responsibilities in checking each others claims".

In this second sequence, you are going to learn how to visit this new city, this new assembly, whose work is able to produce new types of certainties. Not by portraying scientists thinking alone, secluded in some ivory tower, but, on the contrary, by multiplying their connections with a lot of other people and a lot of other institutions and instruments just as we have seen last week. You will have to portray what is often called an "epistemic community" or a "thought collective".

If you have followed the instructions we gave you in sequence 1, your blog must already contain examples of this collective process of ascertaining claims about what the world is like. You most probably have recorded instances of arguments that are, in effect, just so many claims for the existence of phenomena invisible until now. For instance, new drugs that have dangerous side effects, or new planets that have been discovered around other stars, or a new study about the link between poverty and cognitive abilities, and so on and so forth.

The reason that we insist on your following "new" claims is that it will be easier than with older ones for you to discover the collective process that might, in the end, ascertain them or, on the contrary, dissolve them out of existence. Once they are entrenched into the stock of ascertained knowledge, it is much more difficult to detect where they came from.

If I ask you what is the atomic composition of water, chance is that you answer, unhesitatingly, "H20". This statement is certainly accurate, but if I then ask you: "Show me the proof of this statement", you will be at a loss, because it is so well

ascertained that no one bothers anymore to establish it through a publication, a blog, a tweet or a newspaper. It is settled. And if I insist, you will shrug it off and say "Everyone knows that", "Look for yourself in any encyclopedia" or even more bluntly: "It's part of nature". In effect, the statement has been, to use an expression from the social sciences, fully "naturalized". It is part of the landscape. All traces of its production have vanished.

Which is great. It means you don't have to bother proving it. You may safely use this statement to predict another one. You could say, for instance: "Since the atomic composition of water is H20, it should be possible to invent a process that separates hydrogen from oxygen". In such a claim, the first part of the sentence, what is called the "premise", is more certain than what comes next (by the way, hydrolysis is still a very hot topic). Your interlocutor is asked to concentrate on the latter part of the claim and not on the former. You have built a sort of downhill slope directing the attention and then the movement of those you address from the nature of water to what you could do with this knowledge.

We all live in such a highly differentiated landscape of arguments, constantly negotiating our ways through through channels and valleys, across plains, and carefully up and down cliffs. That's the geography we have to become familiar with by learning to map it. [carte du tender]

As you have noticed in your blogs, we are all bombarded, every day, by people who make claims that are based on premises that result from them having taken a prior statement for granted. Or, this is where the problem lies, that they say, are fully naturalized. Why is it a problem? Because, when "people say" such and such a statement has to be taken for granted, is it really so? Are we considering what exists in nature, or what is said, by some people, about what exists in nature? In other words, is it a statement or a fact?

This is such a big philosophical, ethical and practical problem that there is no way to tackle it directly (we will come back to that big problem in sequence 4). For now, we are going to tackle it by taking a very simple route: we will use nothing more complicated than quotation marks!

There is the joke that you may easily recognize someone from the humanities because they constantly make this gesture with both hands: they semaphore "scare quotes"! Well, you should not be scared nor should you spare quotation marks. Quotations are a great way to protect a statement against too quick a naturalization. That is a great instrument of critique. It is a great tool of the humanities and it is precisely by using them a lot that we make ourselves human and scientific!. And once you have learned when and where you multiply them then you will understand why, when you remove them, it is for good.

For this week you need to learn no other skill than that of comic book writers when they draw bubbles around a statement and put it in someone's mouth. As soon

as you do this, a statement that was floating around becomes grounded. Then nothing will stop you from drawing the rest of the scene. It is uttered by someone in a story that has many characters, a whole décor, and that has a beginning and an end. You will quickly learn to reconstruct where the statement comes from and to specify the profession, setting, and equipment of those who have launched it. You have in effect sourced the origin of the claim. Just as any journalist would do.

But then, you will soon realize, this is going to lead you much further. First, you will be led step by step to different types of media. If you have started with a post in a blog, you might have been referred to a newspaper, and from there to a report, from which, most probably, you will be pointed toward what is called the "scientific literature". If there is no path leading you from trace to trace, along such a paper trail, chances are you are dealing with one of those rumors that can be neither proved or disproved.. Abandon it. It is probably just someone's opinion. There is no way to build any cognitive thinking around that one. Choose another example.

But once you reach a more esoteric document, don't panic. There is no way to get used to scientific humanities without learning how to find your way through scientific literature. It is the most interesting part of your trip because from the literature you will be led, first to laboratories and research centers, and, from there, to the experimental scenes that form the most fascinating and convincing parts of the papers you have chosen as the source of your little inquiry. Starting from a floating statement, you will have come to the flesh and bone of scientific practice.

The idea of this sequence is that you will respect the certainty of a claim much better once you have become acquainted with how it is produced. At first, you might be horrified to see how difficult it is for a statement to reach the state of an established and indisputable fact. So many intermediary steps, so many precautions to take, so many people involved in discussing it, so much money to spend, so many instruments to assemble. But then you will realize that it is precisely thanks to this collective process of slow and highly mediated fabrication that there are, in the end, solid and robust facts you may safely count on to find your way in the real world. The etymology of the word "fact" is tricky as well as enlightening: it may mean fabricated thus false, or fabricated thus solid. It is the second path we invite you to follow. *Cogitamus* not *cogito*.

INTRO—SEQUENCE 3: HOW TO HANDLE TECHNICAL INNOVATIONS

Look around you: you are most probably surrounded by an amazing number of material devices. Some of them appear very rudimentary and have been around for millennia — a hammer, a basket, a needle; others are so complex that you might have no idea on how nor why it works — the computer on which you work for this class, the microwave in which you heat your mug. Some are already so clearly dated and outdated that they begin to look like works of art — a Buick from the 1950s, an old coffee grinder with a handle just as your grand mother used it, a shot gun from the past century, a sickle from a farm long gone. Some are so costly that you are not allowed nor able to make them work while others look so puzzling in their form and function that you wonder for whom and for what they have been devised. Try to list every material item around you: you will be tired before having gone through one single room — and don't start with the kitchen or the garage!

Those material devices, or to use the term proposed by anthropologists, those "technical artifacts", enter into the quasi-totality of our daily action. Try to cook, to write, to build, to travel, try to garden or to sow without using any artifact whatsoever! Well, you would not go very far. And yet, it is difficult to pay full justice to the mass of work, of action, those artifacts do for us and with us. If you say: "But they are just tools", you don't treat what they do with enough generosity, since obviously without, for instance, an electric saw you would not have even begun to contemplate building a doll house for your little brothers; without a needle, your fingers will never have itched to cut and fashion a dress; and who will have the idea of blowing through a trumpet without a trumpet at hand? Without the help of a computer, how would you have even thought of taking a course with distant Frenchmen in Paris?! In other words, the device made you think of doing new things. So, technical artifacts are at once allowing action and proposing new goals.

Of course, such a complex action — or agency — is pretty difficult to detect when we deal with objects that are so well entrenched in your daily life that you don't even imagine that they might have not been there all along. You take your car without another thought because you want to go somewhere at will: for you, it's just a tool that simply fulfills your desire to move. How could you remember the time, less than a century ago, when the very desire to go far and quickly, in complete autonomy, was slowly made possible, only for wealthy people, by the development of cars against the development of public transportation, especially tramways? How could you? I am pretty sure you have already forgotten the time when you could not send instant messages to your loved ones through your mobile phone.

Don't feel bad about it: such a forgetting is the very function of technical artifacts: once they have been put into place, once they have invented goals for us, we entirely

forget their presence. They simply shape silently the material infrastructure inside which we live.

And that is the big problem we have to tackle in this sequence: artifacts are not isolated bits of engineering brought each spring by the beaks of benevolent storks. They are accompanied by quite a number of other phenomena that we take for granted when we accept to use any of them. Technical artifacts have been devised by people according to plans which might differ from yours quite a lot. Since once in place they disappear from view, those hidden goals will last for very long without you being able to detect what they make you do surreptitiously. Their ability to quickly become silent and invisible makes them incredibly powerful forces in molding our daily work. To use a catch phrase from the field of science studies: "artifacts have politics".

The aim of this sequence is to develop enough interpretative skills to detect, to trace, and may be, one day, for you to influence, such politics. How are we going to do that? Just as we did in the former weeks: I am sure that in gathering material for your blog you have noticed many events that were not about a new piece of knowledge but about the *introduction* of new techniques. For instance, if there is a company in your neighborhood that tries to introduce the oil recovery technique known as "fracking", you will have detected lots of reactions against this technique. Since it is not part of the landscape yet, you can easily see the work necessary to *make* it part of the landscape. You might have noticed less dramatic cases as well: a coffee company, for another instance, is attempting to sell doses of your favorite beverage in minute capsules that seem to conservationists a complete waste of precious material. The more protestations there are, the easier it is for you to take this new process for a violent attempt to modify a tiny part of your behavior. When you read, to take a third example, about militants of free software fighting against the many dangers of proprietary programs, you understand that what seems to run smoothly on your screen might make you do all sorts of things you might not wish to do. All those cases have to be carefully recorded: they are the best entry into the politics of artifacts.

To become attentive to such politics, we are going to treat technical artifacts not as so many "objects" — pieces of material stuff but as "projects". We will add to them everything that allows them to work. You will quickly see that projects are much more lively animals than objects. For one thing, they have a history. They come and go. For another, they are full of people, inventors, financiers, lawyers, ethicists, government officials, politicians, consumers, each of them with his or her strategies, skills and life trajectory. Then, each project attempts at forming a system, that is, at making all the other artifacts around them serve their own goals. They never succeed, of course, but all those aborted systems create a highly complex ecology more entangled than a deep jungle. Then you will discover that projects, even once they have become entire infrastructure, remain pretty fragile. They might break down; a strike may idle them;

another project may render them obsolete; another legal framework may make them too costly. Even when they are said to "run automatically" they need quite a lot of work to keep them up. What you are going to discover is the "life of things" and "the career of objects".

With this sequence, every thing that seems solid will be set in motion; every thing that seems dead material will become alive; everything that seems part of the natural landscape will become a vast building site; everything that seems destiny, will become decision. You will recover a feel and a taste for a material world that has been made, so far, without you, and that, incredibly enough, is almost totally ignored by the field of humanities. But also totally misrepresented by what is called "technical hype". Projects are very, very far from the ideas of control, mastery, rationality, efficiency and progress often associated with "new" techniques. Innovations are fabulous to study but not because they are efficient, because they are so deeply humans. In this sequence, be ready to get your hands wet and dirty. You will have to be attentive to all sorts of little details. God is in the details, but so is the Devil.

INTRO—SEQUENCE 4: HOW TO DEAL WITH CONTROVERSIES

Now that, thanks to your blog, you have learned how to follow complex imbroglios of science, technology and public affairs, we are going to enter into a much more complicated question. You have surely noticed that on the many topics you have been following, be they in health, ecology, sociology, law, politics or economics, the experts who have been mobilized do not always agree among themselves. They seem to be engaged in what "could be called controversies", especially when we give this expression a very wide range of application so that the same term may cover every sort of dissent from minute disagreements between small groups of highly specialized scientists to public issues that mobilize laymen in the street.

On many topics, we find this state of affairs quite normal and there exist procedures to settle those disputes. This is clearly the case in legal matters: since lawyers represent various contradictory interests, we are not surprised that judges and juries have to make up their mind after cross-examination and pleading. This is clearly the case also for political disputes that are solved by votes, referendums or elections. But it is much more surprising to hear that, when dealing with scientific and technical matters, it is often difficult to assemble the advice that settles the case in such a final form. There are often huge disagreements on, for instance, the feasibility of a "smart" electrical network, the profitability of a pipeline, the efficacy of a cancer cure, the predictability of an ecological catastrophe, and so on and so forth. Your blogs are full of those disputes. Unfortunately, for settling such disagreements, there exists no procedure that would be as widely accepted and as thoroughly instrumented as those that exist to settle legal cases. And yet controversies have to be settled for the scientific and technical affairs just as well. We cannot proceed through any course of action in the midst of too many uncertainties. Cases have to be closed.

To delineate such a procedure, is the object of this fourth sequence, a more difficult and risky lesson than the others. We are going to have to learn how to *map controversies* from their beginnings all the way to their end and to recognize, at every step, why they are opened in the first place, how they develop, why they are sometimes closed too quickly or, on the contrary, needlessly reopened. To do so we are going to need to develop a lot of interpretative skills to educate ourselves in having the right taste or the right feel for dealing with the many controversies on which we are so often asked to take a stand. This is where the field of "scientific humanities" really deserves its name.

Let me first review with you three major problems that render such a mapping a difficult enterprise.

The first massive difficulty is that, with very few exceptions, we are rarely ourselves specialists of the detailed content of the case at hand. The likelihood that we ourselves have published any statement on the topic under discussion is nil, if by

"publication" we mean what has been learned in sequence two: a scientific paper in a refereed journal that has been taken up and cited by later peers. And this is true of course if we are a layman in biological, chemical or engineering matters, but this is just as true for biologists, chemists and engineers for the controversies that are raging in the domains that are adjacent to theirs and for which, nonetheless, they need closure to get on with their own business. The fields are so specialized that certainties from one specialty do not easily spill over to the next one. Of course you may decide to become a specialist in the next domain by double checking the results of their papers but, for most topics, this would require a lifetime of learning and, if you don't succeed in becoming a peer of those you criticize, you would end up doing nothing more than needlessly meddling. So in all cases, we have to trust the experts without being able to go inside the details of their proofs.

But *whom* to trust? That's the tricky question. The great solution would be to say: "Trust the scientific community most relevant for the issue at hand". That would be ideal because we could discard all the statements of those who are not scientific - they just have "opinions" not "knowledge" about the issue - or we could discard all the statements which may be "scientific" but "irrelevant" for settling the question. But the problem is that this solution is just that: an ideal. In practice, it is very difficult to establish the limits of what is a "relevant scientific community". Most disputes, when we are drawn to them, begin by claims that this or that scientist is not "really" a scientist or that this type of expertise is not the "most relevant" to close the question. So the problem of whom to trust is not that easy to settle as you can see for yourselves by following the same disputes over several months through your blogs.

So we need another solution if we are to place our trust in this or that party to a controversy for which we will always remain a partial outsider but which needs to be closed first so that we may take action. Naturally, those of us inside the domain we sort of control or survey have a fairly good assessment of who is reliable and who is relevant or not. A good shoemaker will probably know who and where the good shoemakers are just as well as a molecular biologist will assess whom to ask for the most pertinent advice in case of trouble with her experiment. In both cases, this assessment is based on a variety of sensors and captors: the quality of the people, the reliability of the production, the feedback from consumers or colleagues, the length of the track records on which to judge the output, the awards received from such and such academies, and of course the direct testing of the results. Is it possible for *outsiders* to develop quickly at least some of those skills that *insiders* seem to have acquired through a long training? That is the question that the mapping of controversies is trying to answer by developing various tools which, taken together, may act as a prosthesis for not being an insider and still being able to make up one's mind about whom to trust by detecting who is the less partisan party in the dispute.

The second equally massive difficulty is that most protagonists in the controversies will use the adjective "scientific" do describe a statement that is neither "political", nor "irrational". Again, that would be an ideal use of the adjective if it could be used uncontroversially. But unfortunately this is not the case. As you have learned in sequence one, delineating what is "scientific" and what is not scientific is the most difficult thing to do since the autonomy of science is possible precisely because of the number of external factors making such an autonomy possible. As we have seen earlier, stressing only the autonomy of science makes about as much sense as stating that a nuclear reactor is "autonomous": well, yes, it better be, but on the condition that a whole technical system be built around it to hold it tight.

But here we encounter a major problem because if I say "This is not a scientific statement, it's a political one", you will immediately conclude that it is not an accurate objective one, that it has been "distorted" by the biases and interests of those who uttered it. Is "scientific", in the common usage of the word, what has not been distorted by politics on the assumption that left to themselves, completely autonomous states of affairs go just as straight as an apple falling to the ground. And even if you have learned in the three latest sequences that this idea makes no sense, there seems to be no alternative. Either it is "scientific" or it is "rhetorical".

Well, the great advantage of bringing the "humanities" to bear on scientific practice is that in the field of humanities there are a lot of resources to study what is rhetorical because of the field's emphasis on the materiality of language and speech. And if you begin to be attentive to language, as you should be, it is not too difficult to ferret out an alternative to the "science" versus "rhetoric" way of thinking. It is simply that, most of the time, we designate as "scientific" not only a state of affairs coming straight from nature without any distortion, but also a certain *style* of writing papers, reports and documentation. A style where all indications of rhetoric seem to have been erased.

But those signs are there nonetheless, so that we can now differentiate not "science" from "rhetoric" but rather two types of rhetoric, one that erases as much as possible all traces that it is a textual account (it is just a clear and transparent window pane through which the world is seen) and another one that multiplies the tell tale signs that it is indeed a textual account (at the limit it could appear as poetry). So, in spite of the insistence on the difference between "demonstrating" something and "convincing" or "persuading'" someone of something, a difference that dates from the Greek and that is a powerful political way of closing the discussion, we had better learn to map out all the tools that are mobilized in opening or closing discussion. It does not mean of course that there are no incontrovertible facts, it only means that incontrovertibility is the *final* state of a process that has to be followed from beginning to end.

The third major difficulty we have to tackle (I told you this is a tricky sequence!) is that the word controversy itself is controversial... As you will see in considering this hilarious Doonesbury strip, the word is also used to create the impression that a case is still open even when it has been closed tight by experts who are in full agreement about it! The idea is to maintain two sides facing one another even when there are no longer two. This is for instance the case, well known in the United States, where people talk of the controversy over evolution as if there existed another equally scientific camp made up of creationists or lately, "intelligent design" specialists. More politically important, is the idea, forcefully developed by powerful interests, that there is a "climate controversy" as if there were two scientific camps, one made of experts claiming that human action is responsible for "global warming" and another who claims that humans are not responsible for "climate change".

Even though those spurious controversies are extremely popular (especially among the media who love to have two parties on a TV stage as if journalists were judges in the law court) what you are going to learn in this sequence might dispose of them: just consider who are the scientists to trust after you have mapped the controversy. Using the definition proposed in sequence one and two you will have no difficulty weighing the respective sides: who are those who publish peer-reviewed papers? Once you do that, you might see that the two "sides" are not made up of the same type of "experts" at all and that it would be a mistake to talk as if there were two sides. Seeing this does not mean the dispute will stop; it means that you will learn to detect who is more partisan than whom. And that is the best goal that, as an outsider, you may achieve. We will see in the last sequence, what this could mean for the definition of the citizen of a new democracy. But first we have to provide such a citizen with some equipment in order to map out the issues at hand without being intimidated by the many contradictory claims of each party as being "more scientific than thou".

Here learning how to interpret many disjointed evidence is the skill that trumps all the others.

INTRO—SEQUENCE 6: HOW TO UNDERSTAND THE SHIFTING NATURE OF THE NATURAL WORLD?

Now that you have become conversant in scientific humanities, you might be ready to take a larger view of the subject matter and consider a wider span of history, taking humanity as a whole in its relation with science and technology.

You must have realized by now that if you attempt to describe in your logbook all the instances of a link between science, technology and the rest of culture, society or politics, you end up registering almost all the news! Extremely rare are the events that do not depend on the impact of a new piece of technology or which do not appeal to a highly specialized domain of expertise. And this is true for natural as well as for social sciences — and also, as you have now learned to recognize, it is true for all the more obscure disciplines like management, accounting, and logistics, that is, for the myriads of specialists that have rendered themselves necessary for the achievement of any course of action.

And that's the problem we have to tackle now in sequence 6: how is it that science, technology and society have become co-extensive, so that it has become impossible to study one without studying the others? If we grasp this situation, you will be quite surprised to notice that, in spite of this by now obvious phenomenon, common sense tells us that we should keep "science" and "culture" as distinct as possible from one another! How puzzling it is to entertain simultaneously two completely different views of the same world we inhabit. This duality is at the heart of scientific humanities. We will have to tackle it.

To fathom such a contradiction, let's begin with a little thought experiment. Try to take away, one by one, the artifacts which you have to "go through" in order to achieve any action. Start by shutting down the computer on which you watch this video… Careful, your connection with me will be cut off. Then, try to make yourself a mug of coffee. No, no, don't use the coffee machine: it is gone! Now you have to go fetch your coffee beans by yourself and find a way to grind them with a stone. But your car is gone too, and so is public transportation. Sorry to say but you now have to walk to fetch your coffee! If coffee does not grow where you live, say bye-bye to this beverage: you are back to the situation of Europeans before the 17 th century. They had no coffee to stimulate their neurons.

If you want to render this thought experiment more dramatic, read a science-fiction novel like David Brin's The Postman or watch the film with Kevin Costner. You will quickly realize how easy it is to connect a state of technology with a state of society! To the point where one can say that describing a set of artifacts or describing a set of social relations amounts to describing the same thing twice but in a different order. Granted the existence of "a letter with a stamp", a whole civilization is made

alive; or, conversely, for a postman to be given the authority to carry the letter to someone else far away, a whole civilization must be firmly in place.

Now, try to pursue the same thought experiment, not, this time, in the realm of artifacts, but in the realm of expert knowledge. Imagine that historians have disappeared entirely from the surface of the Earth: what would you know of what tradition you inherit? Get rid of cartographers and geographers, and where would you situate your country or your city in relation with all the others? Without archeologists and paleontologists, you would be reduced to a tiny span of history, to a moment isolated in a complete vacuum. Take economists, statisticians and accountants away: gone would be the very idea of an economy to which you belong. You depend on all of them. Without them you end up being just an individual, an atom, a vanishing point.

And this is just the beginning: take away natural history, how would you know of all the species making up the biosphere, and if you find yourself in charge of a hospital deserted by physicians, nurses, biologists and laboratory technicians, what would you make of diseases and epidemics? You will be unable to do anything to save any patient. Biology, physics, and chemistry depend on the institutions of science just as much as the knowledge of ancient Greek or that of Shakespeare Early Modern English depends on the continuing existence of scholars able to inherit the documents of the past and decipher their cryptic readings. Without those domains of expertise, you would be reduced to a know-nothing, a naked moron lost in space and time. You depend so much on the production of expert knowledge, that describing the society you live in or the knowledge infrastructure you depend on, once again, amounts to describing the same phenomenon twice.

Once you have engaged in such a thought experiment, you might want to take a new look at the longer history of humanity in its connection with the extension of technology and the expansion of its knowledge infrastructure. It is not so difficult to do if you consider the notion of the "footprint" that humanity leaves behind in its movement throughout history. Anthropologists, paleontologists, ecologists, and archeologists have reconstructed many different ways for human societies to mobilize elements of the world around them. Although there is no evolution from one stage to the next — as if older societies were more "primitive" or "simpler" than the present ones —, there exists nonetheless a trend that is easily discernible: the growing extent of the footprint of human action throughout the "natural" world.

At the time of Ötzi, the 5000 year-old Ice Age man found preserved in an Alpine glacier along with his clothing and equipment, his footprint and that of his society were tiny compared to the one you leave around yourself today. And yet, he was already transforming his environment to a considerable extent and relied on a subtle knowledge that made him just as dependent on expertise as you do now. However,

Ötzi was most probably able to fabricate by himself all the equipment he carried on his back. We are not. While only archeologists may find the tiny traces his civilization left in the valleys of the Alps, the traces we leave on the Earth are visible everywhere to the naked eye. So, what is different is the *scale* at which this transformation of the natural world occurs and the *extent* of our reliance on a vast knowledge infrastructure, each component of which we do not master by ourselves but only by trusting other specialists.

Such a view of human history might have seemed far-fetched at the time of Karl Marx or provocative at the beginning of the field of science studies, but it has become fairly obvious with the invention, by geologists and climatologists, of the notion of the Anthropocene. You certainly remember, because you have learned it at school, that each moment of the history of the Earth has been given a name: "Permian", "Cretaceous", "Pleistocene" and so on. Those names have been chosen so as to highlight the most important force at work in shaping the face of our planet in that period. Well, it happens that some geologists are arguing that the most important force at work is now humanity taken as a whole. Not you and me individually, but all of us in association with our industry, agriculture, transportation, military infrastructure and communication systems. For geologists, the scale of human intervention in the workings of the Earth system has become as big — if not bigger — than that of volcanoes, rivers, vegetation, oceans, or even plate tectonics. What a change from the time of Ötzi!

The point of interest for us is that, thanks to the dramatic rise of humanity's impact, it becomes obvious that describing human action or describing science and technology amounts to the same thing twice.

And that is the main insight of scientific humanities. If you wish to study the nitrogen cycle on Earth, you will have to take into account the factories in which nitrogen is being fabricated through a process invented by the Nobel Laureate Fritz Haber (1868-1934) and many of his chemistry colleagues at the beginning of the 20th century. You begin with a natural phenomenon and you are led to a highly historical and social event: The German industrial system. But you can tell the story in reverse order: start with Haber and you will be led to an Earth-wide mechanism. Or to take what has become the most canonical example, if you wish to understand the Earth's climate, you will have to factor in the amount of CO2 generated since the industrial revolution by modern ways of life. A "natural process" or a "socio political system"those are the two faces of the same coin. That's what the notion of the Anthropocene as a period of history — but we should really say a period of *geo history* — summarizes in one single convenient concept.

Which leaves us with a big problem: if this is true, why is it so difficult, for common sense, to relate science with the rest of culture? To the point where the main injunction is that the two should remain as distinct as possible so that the authority and autonomy of science, as well as the autonomy and efficacy of technology will not be threatened by the vagaries of politics, the illusions of ideology or the dreams of poetry. Everything happens as if there existed two opposing forms of common sense. That's where scientific humanities encounter politics head on.

INTRO—SEQUENCE 7: HOW TO BECOME A CITIZEN IN THE PUBLIC LIFE OF SCIENCE AND TECHNOLOGY?

As you are now reaching the end of this class, you may be aware that you have more problems on your plate than you have solutions for them! Sorry to have somewhat disappointed you. But I warned you in advance: if you wanted solutions, you should not have taken this course.

What you might have learned along the way, however, is that the ideal solution to all the problems of science and society is just that: an ideal of no practical consequence. It would be nice to still insist on the radical distinction between the domain of Science and the domain of Politics; between the convincing conclusions of objective demonstrations and the uncertain connections of subjective rhetoric. It would be nice because, then, we could dream that ignorance and unreason will finally disappear from the face of the planet. We would just have to wait a little bit more for modernization to be completed. In the end, the power of demonstrations will defeat the vagaries of rhetoric and all human passions.

But as we saw in the last three classes, modernization has had exactly the opposite result: it has multiplied the controversies about what to do with technologies and what to expect from expert knowledge. To the point that we are now faced with two entirely different narratives of the recent human past: one is the Great Story of the Modernizing Frontier marching on; the other of more and more complicated imbroglios of humans with things. In one narrative, we expect more and more Emancipation from material constraints; in the other, many, many more Attachments with material constraints. Whereas we were expecting the glowing light of Modernization to illuminate the whole planet, the planet comes back but in the totally unexpected role of the Anthropocene. (see sequence 6)

Humans and things are always so enmeshed into one another, that it might be more prudent to abandon the ideal solution entirely. We have argued that, in order to handle the many controversial situations that arise from the extension of science and technology in all of our daily encounters, it might be more efficient to develop instead what we have called a set of *interpretative skills*.

It is traditional, I know, to oppose the *demonstrative* power of logical reasoning with the much weaker progress of *interpretation*. To the point that a division has often been made between the disciplines that depend on demonstration — mathematics above all — and those that depend on interpretation — history, law, literature, and, more generally, the humanities. But as soon as you have to find your way into a controversy, you realize that the demonstrations are only part of an overall puzzle, which is to 24 be completed by using educated guesses and common sense. To use a simple metaphor: we are not dealing with a solid continuous land with only a few scattered patches of ignorance that will soon be cleared up up, but with an archipelago of more or less solid demonstrations spread out into a vast sea of ignorance. And to travel

from one island to the next, we need navigation skills. Well, that's what we call *scientific humanities*. A fragile skiff yes, but without it, we would be stuck on one single tiny island of certainty without any vehicle to move on towards others!

The reason why we find it important to develop those interpretative skills, this alternative common sense, is because, whoever we are, at some point we will be summoned, willingly or unwillingly, to become citizens in a polity where we will have to take a stand on issues dealing with science and technology.

Take for instance the case of a first year councilman in Hawaii who is to vote on a motion banning Genetically Modified Organism. In days past it would have been settled faster by appointing a committee of scientists and they would have written a report on which the council would have voted. (Actually, in days of old, there might have been no discussion whatsoever: some state agency would have taken care of the problem without passing through any public debate.) But in this case, the poor councilman finds himself bombarded by letters from his constituencies threatening to recall him him if he votes "no". Appealing to expert witnesses does not help too much either, since even when they have impeccable credentials their positions might be tainted by corporate money. And when he gets to hear scientists from an independent university, the other party points out that the university has been favored by gifts from big corporations. The more he tries to make up his mind, the more controversial it becomes!

He soon realizes that the issue mobilizes a much wider set of arguments than those originating in Hawaii: cancerous rats from a Paris laboratory, Indian farmers committing suicide, big corporations in the Middle West, plus a bewildering range of knowledge new to him about pollens, cross-fertilization, patents, cultivars and papayas. And the councilman quickly realizes that making sense of the political spectrum is just as touchy as making sense of the pollination of plants.

Well, he finds himself thrown into exactly the sort of landscape that we have been exploring all along in this course.

Suppose now that, after you have become conversant in scientific humanities, the councilman asks for your help in mapping out this landscape and in advising him to take a stand. What would you do? This is the problem we have to tackle in this last sequence: how to equip citizens to make up their minds around issues that do not fit in the usual range of what counts as traditionally political? If you have a well-rehearsed set of positions for or against abortion or the minimum wage, chances are you don't have such a settled opinion on genetically modified papayas!

The first problem is of course to convince experts that citizens should have any say in the debate. Even if it is obvious in questions of agriculture and health that concern everybody, it is not always easy to define in what capacity the public should intervene. For instance, if you are a patient suffering from a rare disease, do you have a say on your illness or are you accepted as having a voice only to complain about

your suffering or to support the researchers? If you are a fisherman in South Africa, are you accepted in the debate as having "knowledge" about fish and fishing, or are you accepted there just to learn the facts of the matter or to complain about the esoteric calculations of fishery science?

The second problem is to avoid *meddling* in issues that are often so technically complex that it is impossible to tackle them by a thumbs up or thumbs down as you would do on Facebook. And yet, you have to make up your mind, and in the end there will be a vote. (In the end there is always somewhere a vote, either in corporate board rooms or at the polls!)

What can you do from the outside without meddling and still take a stand? *Mapping controversies* as we learned to do in sequence 4 is one solution. It happens that it is now slightly easier to use tools (often digital tools) to map out the range of opinions and the networks of experts dealing with any given issue. (Your own blogs designed for this course, might play a role in clarifying the issue for those you have followed).

While ordinary citizens cannot deal with all the details internal to an issue, if they have a good ear and nose for controversies, they might be fairly apt at detecting partisanship. This is the essential virtue of public debates provided they are well organized and fairly equipped with controversy maps: they allow bystanders to detect who might be more or less partisan than the other. Although there exist no formal rule for detecting partisanship, it is a feel that can be educated by multiplying the cases.

Partisan detection is essential because every party will be claiming to speak in the name of the Public Good — scientists in the name of Science, corporate interests in the name of Development or Wealth, administrators in the name of Health and Nation, but also militants of all sorts of hues and colors. This is the problem of our poor councilman in Hawaii: every one of his voters claims to know for sure and in no uncertain terms, what is good for the land of Hawaii. So what should he do? He should try to push every party to fly under one's own colors and to state their interest in full. In practice, it means pushing them to describe what we have learned to call a *cosmos*.

To become a citizen in matters of science and technology means that we should learn to sketch the architecture, procedure, participants and protocols of the *quasi-parliaments* where issues that concern a public have to be settled. It is not an easy thing since the shape of those issues and the forum in which they are treated vary enormously and very few of them look like the traditional institutions of politics. But they are parliaments nonetheless where representatives and spokespersons for the many parts of the worlds being mobilized and assembled. This is obviously the case with the issue of climate, but it is fair to say that it has become the case for nearly every item of our daily life. So the task for this final sequence is fairly easy: draw the quasi-parliament around the thing, that is, around the issue, that you have chosen and

define all the parties, their interests, their agendas and the possible compromises they could pass amongst themselves in order to compose a possible solution. Without exploring those quasi-parliaments, many of which are virtual while others are solidly entrenched, it is very difficult to define what a democracy is.

I hope that you have found this course refreshing and maybe also useful. I also hope that we will benefit from your feedback to make it better over the years.