Innovation and Science:
When Science Had Nothing to Do with Innovation,
and *Vice-Versa*

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Abstract

To scientists and their representatives, science and innovation go hand in hand: technological innovation depends on science, or basic research. Students of technological innovation have held the same view for decades, and some continue to do so. In contrast, more recent theories of technological innovation make a clear demarcation between science and innovation: the sources of innovation are many, of which science is only one, one that often plays no role at all.

This paper looks at what innovation means to scientists from an intellectual history perspective, and studies how the concept of innovation entered scientists' discourses. It is documented that, from Francis Bacon to the nineteenth century, innovation is a political concept that had nothing to do with science. The concept got into science gradually only over the last century, following a shift in meaning as a result of its use in useful arts.

After all the *Innovation*, of which they [new experiments] can be suspected, we find nothing will be indanger'd, but only the *Physics* of *Antiquity* (Thomas Sprat, *The History of the Royal-Society of London for the Improving of Natural Knowledge*, 1667).

Il faudrait, pour fixer la nomenclature des plantes, qu'il y eût, dans toutes les parties du monde, des Tribunaux qui se correspondissent; que par une autorité qui leur seroit commune, un changement devint universel, une découverte utile à tous les hommes, et que l'abus qui tient à la manie de l'innovation, fût sévèrement réprimé (Pierre Bulliard, *Dictionnaire élémentaire de botanique*, 1800).

Introduction [1]

To many theorists of innovation, science (basic research particularly) is at the origin of innovation. To others, there is no relation between science or invention and innovation. Today, it is commonplace to distinguish innovation from invention. To the economist Josef A. Schumpeter, the most cited author on the distinction – although he is not the inventor of it –, "innovation is possible without anything we should identify as invention and invention does not necessarily induce innovation". Invention is an act of intellectual creativity and "is without importance to economic analysis" (Schumpeter, 1939: 84-85). Here, Schumpeter is simply putting into print a long-standing representation of innovation, that between the speculative and the operative (Francis Bacon). Innovation is action (introducing something new into the world), while invention is purely mental (discovering or inventing something new). [2] Just to take one example, in the late eighteenth century the English philosopher Jeremy Bentham distinguishes between "operation upon matter" ("making known the discoveries to the world"), which is the task of "projectors" (the technological innovators of the time), and "operation upon mind" (talent, or as others call it, genius) (Bentham, 1793-95: 49). The French sociologist Gabriel Tarde holds the same representation. He distinguishes theoretical invention (scientific discoveries) and practical invention (industrial inventions) (Tarde, 1902). Similarly, anthropologists of the early twentieth century distinguish discovery from invention (Godin, 2014).

Despite this distinction, and to a certain extent in contradiction to it, in the twentieth century social researchers have put stress on invention as being at the origin of innovation. [3] For example, the first theory of technological innovation, the "linear model of innovation", suggests that innovation starts with science or basic research, then

[1] Special thanks to Robert Bud, Markku Peltonen and Eric Shatzberg for reading and commenting on a first draft of this paper.

[2] Until the early twentieth century, invention meant both *discovering* something that already existed and *making* something new. The conflation or conceptual 'confusion' between the two still remains today.

[3] Students of technological innovation attribute what is called the triple sequence "invention-innovation-diffusion" to Schumpeter. However, to Schumpeter invention is not the source of or a step in the process of innovation. The sequence comes rather from the disciples of Schumpeter at MIT and others (Godin, 2014a).

undergoes applied research, followed by development (Godin, 2006). This theory has been much criticized since it appeared in the late 1940s (Godin and Lane, 2013). Yet, it gave rise to studies by the dozens on measuring the link between science or research and development (R&D) and innovation. The theory also continues to feed policies and remains in the background of many alternative "models" of technological innovation.

What role does innovation play in science, and vice-versa? This paper provides an answer from a conceptual perspective. The paper is a contribution to the intellectual history of innovation. It studies how "men of science" from the seventeenth to the nineteenth century understood innovation. From the sixteenth century onward innovation is an essentially political and contested concept (Godin, 2012). The reader is invited to forget his modern idea of innovation as economics (technology). This representation is less than hundred years old. Before the twentieth century, the concept of innovation is pejorative. To be sure, to the ancients and to the men of the following centuries innovation is everywhere, but everyone denies he innovates: "innovativeness yes, innovation no". The rehabilitation – and theorization – of innovation as a concept is a modern idea that started between 1750 and 1850 and got a hearing in the twentieth century.

This paper documents that "science" (natural philosophy) and innovation are two entirely different concepts – and things – that no one then thought of combining. Science is method while innovation is politics. Innovation as a concept entered the scientific vocabulary with a positive meaning much later, in the twentieth century. The first part of this paper documents men of science's representation of innovation before the nineteenth century. Francis Bacon (1561-1626) is studied as an eminent example of this representation in the following sense. First, Bacon produced thoughts on both science and innovation. It is shown here that, to Bacon, the term innovation is pejorative, as it is to most people of his time. Second, Bacon does not mix science and innovation. These are two distinct spheres of activity. Third, Bacon's "solution" (gradualism) to the paradox of

innovation [4] was much cited and adopted later on: one must innovate slowly, as time itself does. The second part of the paper documents when, how and why the concept of innovation entered science with a positive meaning. This started gradually in the nineteenth century. It is documented that at that time, the concept of innovation was different from today's dominant definition as artifacts or goods for the market. Innovation then meant the introduction (application) of science or the scientific method into what was then called the useful arts.

Innovation and Representations of Innovation

Continuing a tradition of thought originating during the Reformation, men of the seventeenth century understand innovation as political (Godin, 2010; 2012-13). Such is the view of men of science too. As an innovator, Bacon discusses his project of a new scientific method in terms of novelty and originality but explicitly avoids using the concept of innovation. What is Bacon's innovation and why isn't his innovation an innovation?

"That knowledge has to bear fruit in works, that science ought to be applicable to industry, that men ought to organize themselves as a sacred duty to improve and transform the conditions of life". So Benjamin Farrington describes Bacon's project. "Men must consult nature rather than book" (Farrington, 1951: 3, 7). Bacon's project aimed at the "restoration" (*restauratio*) of the sciences and their alignment to the benefit of humanity's well-being. Bacon believes that the "operative" or practical "works and fruits" of science are and should be the aims of learning. "Natural philosophy shall not vanish in the fumes of subtle or sublime speculations, but shall be operative to relieve the inconveniences of man's estate" (DD 383). [5] Yet, "it is esteemed a kind of dishonour upon learning for learned men to descend to inquiry or mediation upon matters

[4] The paradox states, as David Zaret puts it, that everyone innovates but condemns innovation at the same time (Zaret, 2000: 39-43; 254-57). On discussion of this paradox in the context of change generally, see Ferguson, 1965; Ashton, 1980.

[5] I use Vickers (1996) for *The Advancement of Learning* (thereafter referred as AL) and Bacon's *Essays*; Spedding, Ellis and Heath (1887) for *Instauratio Magna* (IM) and *De Dignitate et Augmentis Scientiarum* (DD); Rees and Wakely (2004) for *Novum Organum* (NO).

mechanical" (DD 413). In contrast, to Bacon, both science and the artificial are on a par (DD 410):

> An opinion has long been prevalent that art is something different from nature, and things artificial different from things natural … Most writers of Natural History think they have done enough when they have given an account of animals or plants or minerals, omitting all mention of the experiments of mechanical arts (...), considering art as merely an assistant to nature, having the power indeed to finish what nature has begun, to correct her when lapsing into error, or to set free when in bondage, but by no means to change, transmute, or fundamentally alter nature ... This has bred a premature despair in human enterprises … The artificial does not differ from the natural in form or essence, but only in the efficient.

It is unanimously admitted today that Bacon is an innovator. His restoration contributed to science as we know it today (Rossi, 1973-74). Two things deserve mention in this paper. First, Bacon is conscious of innovating against the established science. In all his works, Bacon never refrained from qualifying his ideas as "new". Second, Bacon is conscious of resistances to innovation. In a context of order, authority and customs, innovation is forbidden. At the same time, then, that he stresses his innovation, Bacon argues for a middle ground. As Charles Whitney puts it, Bacon uses traditional language to advance novel ideas (Whitney, 1986). "From the fourteenth through the sixteenth century", states Erwin Panofsky, "and from one end of Europe to the other, the men of the Renaissance were convinced that the period in which they lived was a "new age" as sharply different from the medieval past as the medieval past had been from classical antiquity and marked by a concerted effort to revive the culture of the latter ... [But] they experienced a sense of regeneration too radical and intense to be expressed in any other language than that of Scripture" (Panofsky, 1960: 36-37). Writers drew on theology, precedents and existing institutions and norms to justify radical changes.

What Bacon proposes as new science and method has been much studied in the literature, and will not be discussed here. The entire literature on Bacon is concerned with that. [6] The language that Bacon uses has also been studied by Whitney (1986) and some others (e.g. Malherbe, 1985). Yet Whitney does not study "innovation" – although he has a few

[6] Some notable books on Bacon are, to name just a few: Farrington (1951), Rossi (1968), Pérez-Ramos (1988), Peltonen (1996), Zagorin (1998) and Gaukroger (2001).

words to say on Bacon's essay *Of Innovation*. This section concentrates on Bacon's representation of innovation and his use (or rather non-use) of the concept innovation. The section discusses in turn 1) Bacon's innovation, in his own terms; 2) Bacon's consciousness of innovating; 3) Bacon's analysis of resistances to innovation, which led to 4) his refusal to use the concept innovation in his scientific writings.

In the present section, I use innovation as a synonym for novelty and originality, as we moderns understand it. As the paper progresses the reader will learn that this is only one of the meanings of the concept and that, for reasons explained in the later part of this section, it is not Bacon's meaning. To Bacon, innovation and innovativeness (the propensity to innovate) are two different things.

1.1 *Bacon's Innovation*

Bacon's *Advancement of Learning* (1605) is a survey of present knowledge (updated in *De Dignitate et Augmentis Scientiarum*, published in Latin in 1623) and also a plea for the development or reformation and application of knowledge. According to Bacon, from the Creation of the world God has promoted knowledge. Bacon's reading of the Scriptures and the history of the Church suggest to him that, together with the Reformation, "it was ordained by the Divine Providence that there should attend withal a **renovation** and new spring of all other [secular] knowledges" (AL 153). Bacon invites the King to a reformation of learning and the endowment of the sciences: your Majesty "whose youthful and fruitful bed doth yet promise many the like [previous learned kings] **renovations**" (AL 169). [7]

To this end, Bacon produced *Instauratio Magna* (1620), of which the part titled *Novum Organum* develops a new scientific method. Knowledge is actually "false, confused, and overhastily abstracted from the facts" (MI 18). To Bacon, science is "endless repetition of

[7] "To the times of the wisest and most learned of kings belongs of right the **regeneration** and **restoration** of the sciences". That your Majesty takes "order for the collecting and perfecting of a Natural and Experimental History … such that philosophy and the sciences may no longer float in the air, but rest on the solid **foundation** of experience" (MI 24).

the same thing … not new in substance"; it "cannot generate for it is fruitful of controversies but barren of works" (MI 26). Bacon wishes "that commerce between the mind and the nature of things (…) be **restored** to its perfect and original condition" (MI 17).

Science is without "foundation" (*fundamento*). This is Bacon's keyword, together with reconstruction (*instauratio*). "The entire fabric of human reason which we employ in the inquisition of nature, is badly put together and built up, and like some magnificent structure without any **foundation**" (MI 18). There is "one course left", suggests Bacon: to "try the whole thing **anew** upon a better plan, and to commence a **total reconstruction** of the sciences, arts, and all human knowledge raised upon the **proper foundation**" (MI 18), namely natural science (the compilation of facts and experiments). "The only hope therefore of any greater increase or progress lies in a **reconstruction** of the sciences" and "of this **reconstruction** the **foundation** must be laid in natural history" (MI 47).

To Bacon, a reconstruction is a re-edification upon proper, solid and firmer foundations. The reconstruction that Bacon introduces is "a kind of logic" which differs from ordinary logic in three aspects (MI 40-47): "invention not of arguments but of arts"; induction not syllogism; facts and experiments. "It is useless to expect great growth in the sciences from the superinduction and grafting of new things on old; instead the **instauration** must be built up from the deepest **foundations**" (NO 31). It is not a matter of setting up a new philosophical sect, [8] but of building "firmer **foundations** … for the generations to come" (NO 116).

1.2 *Bacon's Originality*

"Not setting up a new sect" … because Bacon is aware that novelty is often ephemeral, a fashion and a frivolity: "Many things are new in the manner, which are not new in the

[8] "I am labouring to lay the **foundation**, not of any sect or doctrine, but of human utility and power" (MI 36).

kind" (AL 211). [9] Bacon is conscious of the originality of his project and claims it explicitly. His keywords are "difference" and "hitherto" (*adhuc*). Bacon compares his project to what has been done until then. "No man **hitherto** has applied his mind to the like" (MI 19). This is "quite new, totally new" (MI 23). Whitney and others have called this the *pathos* of novelty (Arendt, 1963; Whitney, 1986): "The almost violent insistence of all the great authors, scientists, and philosophers since the seventeenth century that they saw things never seen before, thought thoughts never thought before (Arendt, 1958: 226).

Bacon makes three kinds of comparison to distinguish himself. First, he compares his method to that of existing philosophy. The latter is composed of schools, [10] books [11] and idols [12] and is not fruitful of useful arts. [13] "A way must be opened for the human

[9] There are "two extremities, the one Antiquity, the other **Novelty**, so one of them seeketh to devour and suppress the other" (AL 144). There is "vain admiration of any thing, which is the root of all weakness. For all things are admired, either because they are new, or because they are great" (AL 164). On marvels Bacon writes, again: "I find books more than enough filled with fabulous experiments, for pleasure and **novelty**, but a substantial and methodical collection of Heteroclites or Irregulars of Nature well examined and described I find not" (DD 381).

[10] "All the tradition and succession of schools is still a succession of masters and scholars, not of inventors … In the mechanical arts we do not find it so; they, on the contrary are continually growing and becoming more perfect …. Philosophy and the intellectual sciences, on the contrary, stand like statues, worshipped and celebrated, but not moved or advanced …. They fall to the servile office of embellishing certain individual authors" (MI 27). "Their aim has been not to extend philosophy and the arts in substance and value, but only to change doctrines and transfer the kingdom of opinions to themselves" (MI 30).

[11] One of the sources of error in philosophy is "veneration of those works whose abundance has long since been available to the human race" (NO 85).

[12] Two of Bacon's four idols are related specifically to philosophy: 1. Idol of the Market (words) (NO 43; 59-60): "empty disputes, countless controversies and complete fictions". This "has made philosophy and the sciences sophistical and inactive". "Great and solemn disputes of learned men often end in controversies about words and names". Bacon identifies two kinds of such idols: "names of things which do not exist"; "names of things which do exist but are muddled, ill-defined, and rashly and roughly abstracted from the facts". 2. Idols of the Theatre (philosophies, or theories) (NO 44; 61-65). "Theories fit for the stage and by misguided laws of demonstration". To Bacon there are three kinds of false philosophy: a) Sophistical: "Neither securely established nor carefully examined and weighted". b) Empirical: based "on a few experiments". c) Superstitious: "intermingle theology and traditions".

[13] "All those who **before me** have applied themselves to the invention of arts have but cast a glance or two upon facts and examples and experience, and straightway proceeded, as if invention were nothing more than an exercise of thought" (MI 33). Mechanical arts are "neither many nor profound", "attributable only to man's patience (…) and hand or instrument"; they "depend on just one or two of nature's axioms"; there is "poverty and barrenness of facts and discoveries"; "with philosophy and the intellectual arts … the discovery of useful works came to a standstill"; libraries are full of books but "repetitions" and scantiness of the matters; alchemists "have found out a fair few things and endowed men with useful discoveries" but based on tradition and craft; natural magic is speculation "suited to admiration and **novelty** and not to fruitfulness and utility" (NO 85).

understanding **entirely different** from any **hitherto** known" (MI 25). [14] The second comparison Bacon makes is with antiquity. Certainly, "we have no reason to be ashamed of the discoveries which have been made [by] the ancients", claims Bacon, "but before we can reach the remoter and more hidden parts of nature, it is necessary that a more perfect use and application of the human mind and intellect be introduced" (MI 32-33). [15]

Finally, Bacon compares himself to great statesmen and politicians. On the one hand, he compares himself to rulers in a positive sense. [16] Famous rulers like Julius Caesar or Alexander the Great "did greater things in fact than those shadowy heroes [the "projectors"] [17] did in fiction" (NO 87). "I promise myself the fortune of Alexander the Great" (NO 97). [18] On the other hand, Bacon stresses the difficulty of innovating –

[14] *Instauratio Magna*: "I begin the inquiry nearer the source than men have **heretofore**; submitting to examination those things which the common logic takes on trust" (MI 43). "My history **differs** from that in use (as my logic does) in many things" (MI 47). "I drag into light many things which **no one** who was not proceeding by a regular and certain way to the discovery of causes would have thought of inquiring after" (MI 49). "In the selection of the relation and experiments (…) I have been a more cautious purveyor than those who have **hitherto** dealt with natural history" (MI 49). *Novum Organum*: "The mind has been invaded by the habits, hearsay and depraved doctrines of daily life, and beset by the emptiest of *Idols*". "There remains but one way to health and sanity: to do the whole work of the mind **all over again**". "I mean to open up and lay down a **new and certain** pathway". "My business is to open up **a completely new** route for the intellect, one **unknown and untried** by the ancients" (NO preface). "There is no hope save in the ***Regeneration*** of the sciences by eliciting them systematically from experience and founding them **afresh** – which **no one** (I judge) will claim has been done or thought of **before**" (NO 97). We must "seek and get a greater abundance of experiments, an abundance of a kind different from that made **hitherto**; we must also bring in a quite **different** method, order, and process" (NO 100). "This has **never been done before**" (NO 104).

[15] "It would not have been difficult for me to attribute what I have to say to ancient times" in order "to get testimonials and prestige in the way that parvenus do when, with convenient genealogies, they construct and cobble up a noble ancestry for themselves by forging links with some ancient pedigree". But "the discovery of things is to be sought not from the shadows of antiquity but from the light of nature" (NO 122). "People will perhaps think too that I am only reinventing the wheel and that the ancients themselves followed the same route as I do". But "that was not natural history and experience" (NO 125).

[16] There are two differing "abilities" in princes, suggests Bacon in one of his *Essays*: "those which can make a small state great" and those which "bring a great and flourishing estate to ruin and decay". It is the duty of a prince to "add amplitude and greatness to their kingdoms by introducing ordinances, constitutions, and customs … that may sow greatness to their posterity and succession" (*Of True Greatness of Kingdoms and Estates*, 1612). In *The Advancement of Learning*, Bacon describes how Hadrian, because he was learned, innovated. Hadrian spent his whole reign for "**re-edifying** of cities, towns and forts decayed, and for cutting of rivers and streams, and for making bridges and passages, and for policing of cities and commonalities with new ordinances and constitutions, and granting new franchises and incorporations, so that his whole time was a very **restoration** of all the lapses and decays of former times" (AL 157).

[17] Projector was the name given to the technological innovators of the time.

[18] In *De Dignitate et Augmentis Scientiarum*, Bacon gives analogies between politics and science as examples of axioms (laws) not peculiar to a particular science but to all of them (or first philosophy): "Things are preserved from destruction by bringing them back to their first principles is a rule in Physics;

because of politics specifically – as compared to the benefits that accrue from innovation in science. Inventions "can reach out to the whole human race, whereas political improvements affect men in particular localities only, and while the latter last for but a few generations, the former as good last forever. Moreover improvements of political conditions seldom proceed without violence and disorder, whereas inventions enrich and spread their blessings without causing hurt or grief to anybody" (NO 129). [19]

1.3 *Resistances to Innovation*

Bacon admits that innovating is not an easy affair. Civil governments (monarchies in particular) are "hostile to suchlike **novelties** [theories], even the contemplative ones, so that men dealing in them risk harm to their fortunes and not only go unrewarded but are open to contempt and spite" (NO 62). In politics and religion things are worse. "Political **novelty** is riskier than intellectual. In affairs of state even change for the better brings fears of disorder, since civil government rests not on demonstrations but on authority, consent, reputation, and opinion" (NO 90).

Customs and preconceptions form Bacon's second argument explaining resistances to innovation. "Nothing finds favour with the many unless it appeals to the imagination or ties the intellect up in the knots of common notions" (NO 77). Discovering the new is "rejected at first" (NO 92). To Bacon, people "anticipate the new from what they know of

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the same holds good for Politics (as Machiavelli rightly observed), for there is scarcely anything which preserves states from destruction more than the **reformation** and reduction of them to their ancient manners". "Whatsoever contributes to preserve the whole state in its own nature has greater power than that which only benefits the particular members of that state" (DD 407-8). "The force of an agent is increased by the reaction of a contrary is a rule of Physics. The same has wonderful efficacy in Politics, since every faction is violently irritated by the encroachment of a contrary faction" (DD 408).

[19] The French Encyclopedia of 1751 put it similarly: Mechanical "inventions have the advantage over political enterprise in that they bring about the public good without harming anyone. The most spectacular conquests are bathed only in sweat, tears, and blood. He who discovers some secret useful to life, such as, for example, the dissolution of stones in the bladder, would not have to fear the remorse that is inseparable from glory where crime and unhappiness are mingled. The invention of the compass and the printing press opened wider horizons and beautified and enlightened the world ...". "For the success of this enterprise, however, it is necessary that an enlightened government be willing to grant it a powerful and constant protection against injustice, persecution, and the calumny of enemies" (Jaucourt, Art. "Invention", *L'Encyclopédie*).

the old". [20] Bacon gives examples of new inventions and their reception: artillery ("dismissed out of hand"), silk ("the last thing to have entered their heads", "laught at", a "dream"), compass ("fancy", "beyond belief") and printing (NO 109). "In a new enterprise it is not only strong attachment to received wisdom that contributes to prejudice but also a mistaken preconception or advance view of the enterprise in question" (NO 115).

But why, in spite of the resistances, does Bacon welcome innovativeness in science? Because science is source of progress. "Studies are kept imprisoned in some few authors' writings, and he who quarrels with them is instantly attacked as a troublemaker thirsting for **novelty** … But in the arts and sciences, as in mines, all ought to echo the sound of new works and further advancement" (NO 90). And he continues as follows: "Consider (if you will) the difference between the life of men in any of the most civilized provinces of Europe and in one of the most savage and barbarous regions of the New Indies … This difference does not spring from soil, climate, or bodily constitution but from the arts". The art of printing, gunpowder, and the compass "have altered the whole face and state of things right across the globe". "No empire, no sect and no star seem to have exerted a greater effect and influence on human affairs than these machines" (NO 129). [21]

1.4 *Minimizing Innovation*

Resistances to innovation bring Bacon to a middle ground. "Some intellects are captivated by admiration of antiquity, some by love and infatuation for **novelty;** but few are judicious enough to steer a middle ground, neither ruining what the ancients rightly

[20] **"**Nor is it easy to pass on or to explain what I have in mind, for people will still make sense of things new in themselves in terms of things which are old" (NO 34). "Some things already discovered are of a kind that before their discovery the least suspicion of them could scarcely have crossed anyone's mind, but a man would simply have dismissed them as impossible. For men are accustomed to anticipate the new from what they know of the old, and in the light of fancies informed and colored by the latter; but this way of thinking is utterly fallacious, since many of the things we seek from the fountains of nature fail to flow in the usual channels" (NO 109). "People will no doubt "imagine that my discoveries rest on false and doubtful **foundations** and principles … Such things necessarily occur when we are starting off" (NO 118). "In the course of discovery the human mind is on many occasions generally so sloppy and badly set up that it begins by distrusting and soon after despising itself; at first it does not believe that any such things can be discovered" (NO 110).

[21] Rees and Wakely translate machines (*mechanica*) as innovations.

laid down nor despising what the new men rightly put forward" (NO 56). To be sure, "knowledge which is new and foreign from opinions received, is to be delivered in another form than that which is agreeable and familiar" (AL 235). But this has to be done with "a mind of **amendment** [improvement] and proficience [progress], and not of change and difference [dispute]" (AL 299). To this end, Bacon stresses that he uses old terms for novel conceptions. [22]

Bacon also uses both antiquity and nature to legitimize his innovation. We have seen above that he contrasts his project to antiquity. But he also makes analogies with the ancients at the same time. Bacon does not launch an attack on the ancients nor present philosophy: "the honour and reverence due to the ancients remains intact and inviolate" [23] Bacon's project is also "copied from a very ancient model", that of "the world itself and the nature of things and of the mind" (MI 23). Bacon uses nature (time) as his model. In the essay *Of Innovation* (more on this later), Bacon suggests that "men in their **innovations** follow the example of time which innovates greatly, but quietly and by degrees scarce to be perceived". [24]

For our purpose, it needs to be stressed that Bacon never discusses his scientific project in terms of "innovation". His vocabulary is rather composed of "new" and "reconstruction"

[22] "I retain with scrupulous care the ancient terms … I recede as little as possible from antiquity ... Stirred by a spirit of difference and contradiction to wage war on all antiquity [Aristotle] coin[ed] new words of science at pleasure (…) for Glory and drawing followers and disciples" (DD 414-15). Aristotle "learnt that humour from his scholar [Alexander the Great] , whom perhaps he emulated, the one aspiring to conquer all nations, the other to conquer all opinions, and to establish for himself a kind of despotism in thought" (DD 415). I desire "to ground a sociable intercourse between the old and the new in learning …: retain the ancient term, though I often alter their sense and definitions, according to the moderate and approved course of **innovation** [*novandi*] in civil matters, by which, when the state of things is changed, yet the forms of words are kept" (DD 416). The same argument is offered in *The Advancement of Learning*, yet the word innovation is absent; alteration is used instead (AL 193-94).

[23] "I have no intention of toppling the philosophy which flourishes at present". "The honour of the ancients and of all the rest remains unimpaired, for I am not comparing wits and faculties but ways (NO 32). "The philosophy which I adduce will be of very little use in these matters". There are two types of learning, "in no way hostile or set apart from each other", one for "cultivating the sciences and the other for discovering" (anticipation of the mind, interpretation of nature). Bacon holds the same discourse again at the end of *Novum Organum*: "Whether I long to raze and destroy the philosophy, the arts and the sciences now in use"? "I have no intention of interfering with the arts now flourishing". What I am bringing in will not be much use in these affairs" (NO 128).

[24] In *New Atlantis* (1627), Bacon describes his utopian laboratory (Salomon's house) as *imitation* of nature particularly when he discusses instruments.

and the like (restoration, regeneration, renovation, instauration, foundation) and terms for what is called today originality. Bacon has learned Machiavelli's lesson (Machiavelli, *The Discourses*, I, 25): he chooses to keep old words for new ideas and he uses similitudes to communicate the new. This has already been studied by Whitney (Whitney, 1986:144-58). [25] Yet Whitney has not studied "innovation", perhaps because Bacon does not use the word, at least in his scientific writings. The word "innovation" appears only once in *The Advancement of Learning*. [26] There is no use of it in *Instauratio Magna* (including *Novum Organum*). *De Dignitate et Augmentis Scientiarum* does not use it either, except as an example of commonplaces or views on innovation, discussed *utramque partem* (DD 9 178-79). [27]

Bacon is not alone. In seventeenth-century scientists' writings the new is everywhere, as Lynn Thorndike has documented from a study of titles (Thorndike, 1957). But not innovation. Innovation is too radical. As "conservative reformers", scientists dissociated their project "from any radical reform of church, state, the economy of society … and couched their reforming sentiments in vague terms of improving man's health and estate through science" (Jacob and Jacob, 1980: 253). Given the risky nature of the scientific enterprise, scientists needed to distance themselves from radicalism and write in line with restoration values (Hunter, 1995). As Christopher Hill puts it, in a world "where innovation, novelty were dirty words traditional authorities had to be found for the untraditional" (Hill, 1969: 243). From Isaac Newton (Baillon, 2002) to Thomas Reid [28] to

[25] Regeneration has a Christian overtone. It has the sense of rebuilding and replacement (Whitney, 1986: 91). Restoration is back to original. Instauration is renewal. Whitney argues, following Erwin Panofsky, that Bacon does not use "renovation" because of a pejorative meaning. This is a mistake.

[26] On forms (laws), Bacon writes: "there can hardly be discovered any radical or fundamental alterations and **innovations** of nature either by accidents or essays of experiments, or from the light and direction of physical causes; but only by the discovery of forms", namely the study of causes (AL 201).

[27] *De Dignitate* includes two variants of the word: 1. *novandi*. On retaining ancient terms, Bacon writes: "I often alter their sense and definitions; according to the moderate and approved course of **innovation** in civil matters, by which, when the state of things is changed, yet the forms of words are kept" (DD 8 483-84) 2. *innovari*: this is Bacon's translation of AL 201 (DD 8 513) – see footnote 26.

[28] Making "**innovation**" in philosophy ("using new words and phrases, or giving a different meaning to those that are received") is "hardly possible" because the "language of philosophers … is so adapted to the prevailing system". Innovation is "a liberty which, even when necessary, creates prejudice and misconstruction, and which must wait the sanction of time to authorize it". "**Innovation** in language, like those in religion and government, are always suspected and disliked by the many, till use hath made them familiar, and prescription hath given them a title" (Thomas Reid, 1796: introduction).

the opponents of the Royal Society like Meric Casaubon [29] and Henry Stubbe, [30] from satirist Jonathan Swift [31] to political philosophers like Edmund Burke, [32] innovation is a word of accusation against those "hunting after novelties", as Casaubon puts it. But above all innovation is revolutionary and destructive of the established order (Maierus, 1656:133-34):

> They [the "mysterious Society of wise and renowned Philosophers"] who bend their thoughts to change Commonwealths, to alter Religion, to **innovate** the Arts make use of very often most despicable instruments to doe their business … Such causes (I say) have produced many tumults and confusions … where men have been acted by vain thoughts and foolish dreames … Instead of Reformation, they have disturbed all order, and law … In all these things they were belyed and abused.

Bacon has a similar representation of innovation. He makes no use of "innovation" in his scientific writings, despite his innovativeness, his consciousness of innovating and his use of "new" everywhere, including in titles (*Novum Organum*; *New Atlantis*). [33] This is not a semantic issue. Rather, it has to do with the fact that at the time, innovation had a very specific meaning, not appropriate to science. Innovation is political change. In this sense, it is pejorative. [34] It has nothing to do with originality – not yet – but is destructive of the established order (Godin, 2012; Godin and Lucier, 2012).

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[29] Certainly, natural philosophers "abhor all **innovation**" in religion (Casaubon, 1669: 18), but they are nevertheless "hunting after novelties" (Casaubon, 1669: 22). The "prodigious propensity of **innovation** in all kind, but in matters of learning particularly … [Yet, there are] secrets of Nature, or of Heaven, if you will, which none will, upon pretence of any art, attempt to dive into" (Casaubon, 1668: 13-14).

[30] Stubbe uses many words to attack the scientist, among them "innovator": novelist (novelists), virtuoso, comical wit, new-fashion'd philosopher (Stubbe, 1670b). "To conquer [Flanders and lower Germany] there are but two wayes left now to be taken: the first of which is to sow the Seeds of *Division* amongst them: and the second to draw them forth of their own Countrey. *Cadmus* having a design of erecting a Monarchy at *Thebes*, whither he came a *stranger*, is said first to kill a *Serpent;* by which was signified, the Defence and Safe-guard of *Thebes:* and then afterwards to sow the *Teeth* of it; that is to say, to scatter abroad the *Poyson* of *Desire of* ***Innovation***, and an earnestness to be instructed in the knowledge of *Learning*, namely in such *new Sciences* and *Arts*, as he had brought over with him from his own Countrey. And hence *Souldiers* are said to spring up, who through *mutual discord*, slew each other" (Stubbe, 1670a: 177)

[31] Jonathan Swift on Descartes and others, the "grand **innovators**" who "reduce the notions of all mankind exactly to the same length, and breath, and height of his own… This is the first humble and civil design of all **innovators** in the empire of reason" (Swift, 1704: 80).

[32] "Men of letters, fond of distinguishing themselves, are rarely averse to **innovation** … What they have lost in the old court protection, they endeavoured to make up by joining in a sort of incorporation of their own [the academies]" (Burke, 1790: 109-10).

[33] Malherbe (1985) has noted a similar discrepancy between Bacon's use of novelty (*novitas*) and new (*novus*) in *Novum Organum* (5 occurrences versus 109 occurrences).

[34] Certainly, there exist (a few) positive thoughts on innovation and science during the seventeenth century, but they are the exception. Moreover, most come after Bacon. One example is Walter Charleton in a

Nevertheless, there are works in which Bacon uses the word innovation: his moral and philosophical essays and other works than the scientific ones. Bacon's essays (1625) cover many things, some of them already touched on above. For example, *Of Customs and Education* discusses the "tyranny of custom": men "do as they have done before". [35] *Of Unity in Religion* is on quarrels and divisions or controversies of words (in religion). [36] *Of Honour and Reputation* deals with novelty (versus imitation) as a source of honour. [37] *Of Vicissitude of Things* is about how "matter [is] in a perpetual flux". [38]

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dialogue on the existence of God and the immortality of the human soul demonstrated by reason. In the first dialogue, Athanasius paints a positive portrait of the "Heroicall Wits among our Country-men, who have addicted themselves to the Reformation and Augmentation of Arts and Sciences" (Charleton, 1659: 33). Lucrecius replies and asks "why may we not refer these ***Innovations*** in Philosophy, Physick, and the Mathematics … rather to the English Humours of affecting new Opinions, than to any reall defects or errors in the Doctrine of the Ancients" (Charleton, 1659: 51). Athanasius agrees on the "pronesse of the English Genius to Novelties". Yet, he continues with an analogy to the Reformation: "It hath been the Reformation, that drew on the Changes; not the desire of Change, which pretendeth the Reformation" (Charleton, 1659: 52). Right reason drew the changes. A third interlocutor, Isodicastes, agrees: "The Ancients indeed, (thanks be to their bounteous industry) have left us large and noble Foundations; but few compleat Buildings" (Charleton, 1659: 53). Another example is *A Brief Account of the Sect of Latitude-Men* from Simon Patrick. Patrick looks at the supporters of the new philosophy, or latitude-men as some call them. In reality, latitude-men are good Protestants, according to Patrick. Latitude-men is just a name used by the critics, which "serves to talke of when all other discourses fails" (Patrick, 1662: 5). To be sure, latitude-men are innovators, but in the sense of return to the original doctrine of the Church only. "I hear some men say, all **innovations** are dangerous … *new Philosophy* will bring in *new Divinity*… [Yet] true *Philosophy* can never hurt found *Divinity*" (Patrick, 1662: 22). Even the Church believes so: the priests are encouraged to skill themselves in nature, the "new kind of weapons" in the "Artillery" of the Church's enemies. "Let not the Church send out her Souldiers armed with Dock-leaves and Bullrushes, to encounter swords and Guns" (Patrick, 1662: 24).

[35] The essay is on "the force of custom upon mind and body", what Bacon calls the "reign or tyranny of custom". "Men's thoughts are much according to their inclination, their discourse and speeches according to their learning and infused opinions …. There is no trusting to the force of nature nor to the bravery of words, except it be corroborate [confirmed] by custom". "The predominancy of custom is every where visible … Men … do just as they have done before". "Custom is the principal magistrate of man's life". Education "is, in effect, but an early custom".

[36] Quarrels and divisions about religion, discordant and contrary opinions, controversies, heresies and schisms are "the greatest scandal (...), more than corruption of manners". There are two kinds of controversies: "The one is when the matter of the point controverted is too small and light, not worth the heat and strife about it, kindled only by contradiction [variety but no division] .... The other is when the matter of the point controverted is great, but it is driven to an overgreat subtility and obscurity, so that it becometh a thing rather ingenious than substantial [it intends the same thing] .... The nature of such controversies is excellently expressed by St. Paul *Shun the profane* ***novelties*** *[novitates] of terms, and the objections of pseudo-knowledge*. Men create oppositions which are not, and put them into new terms …". Bacon argues against extremes (sanguinary persecutions). The same recommendation appears in the essay *Of Vicissitude of Things*.

[37] "If a man perform that which hath not been attempted before, or attempted and given over, or hath been achieved but with so good circumstances, he shall purchase more honour than by effecting a matter of greater difficulty or virtue, wherein he is but a follower". As examples, Bacon cites men acting for the good of the commonwealth, or political figures: founders of state, princes, saviours, and those who sacrifice

Three essays discuss innovation using the word as such. In *Of Youth and Age*, Bacon discusses how young men, although inventive, commit the "error to **innovate**", which draws inconveniences or damages. [39] In *Of Seditions and Troubles* (1612), a Machiavellian text, Bacon suggests that "the Causes and Motives of seditions [against the State] are **innovation** in religion, taxes, alteration of laws and customs, breaking of privileges, general oppression, advancement of unworthy persons, strangers, dearths, disbanded soldiers, fractions grown desperate, and whatsoever in offending people joineth and knitteth them in a common cause".

The third essay is *Of **Innovation*** (see Appendix 1), an essay produced some years before the controversy on innovation in the English Parliament in 1628-29 and among clerics in the late 1630s-early 1940s (Godin, 2010). This essay and the date of its writing say much about a concept which had already been contested for some time. The essay was first put into commonplaces on (for and against) innovation in *De Dignitate et Augmentis Scientiarum* (Appendix 2). The essay also makes use of Bacon's early thoughts from writings going back to 1604 (see below).

This essay is the key to understanding Bacon's representation of innovation. To Bacon, innovations "at first are ill-shapen". They "are like strangers" because "what is settled by custom ... is fit ... whereas new things piece not so well .... They trouble by their

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themselves to death or danger. In *The Advancement of Learning*, Bacon also discusses honours to "inventors and authors of new arts, endowments, and commodities towards man's life", as in antiquity. While the heroic honours are "confined within the circle of an age a nation", the latter are "like the benefits of heaven, which are permanent and universal", "without noise or agitation" (AL 154). With the *New Atlantis*, Bacon added a new type of men eligible for honour, ordinary men: inventors to whom a gallery of statues is proposed in Salomon's house.

[38] "Salomon saith, *There is no new thing upon the earth ..., all **novelty** is but oblivion*". The essay is on how "matter is in a perpetual flux": nature (deluges, earthquakes), religion ("new sects"), states (wars). "Certain it is that the matter is in perpetual flux, and never at stay … The greatest vicissitude of things amongst men is the vicissitude of sects and religions". "In the youth of a state arms do flourish; in the middle of a state learning; and then both of them together for a time [;] in the declining age of a state, mechanical arts and merchandise".

[39] Men of age "adventure too little", while "the invention [inventiveness] of young men is more lively …; and imaginations [ideas, projects] stream into their minds better". "Young men are fitter to invent than to judge …, are fitter for new projects than for settled business". The errors of young men are: "care not to **innovate** [have no qualms about] which draws unknown inconveniences [damages]", "embrace more than they can hold", "use extreme remedies".

inconformity". Yet, "he that will not apply new remedies, must expect new evils": "A forward retention of custom, is as turbulent a thing as an **innovation**". Bacon's proposal is "That men in their **innovations** would follow the example of time itself; which indeed **innovateth** greatly ["time is the greatest **innovator**"], but quietly, by degrees scarce to be perceived". "It is good also, not to try experiments in states, except the necessity be urgent, or the utility evident; and well to beware, that it be the **reformation** that draweth on the change, and not the desire of change, that pretendeth the **reformation**. And lastly, that the **novelty**, though it be not rejected, yet be held for a suspect". [40]

Such a gradualism is precisely what Bacon does in his scientific writings: [41] 1) not completely rejecting the ancients (there is "no reason to be ashamed of the discoveries which have been made ... by the ancients", MI 248), being critical of both the ancients and moderns ("let not anyone be dazzled either by the great names of ancient philosophers or the great volumes of modern", DD 385); 2) not rejecting religion completely ("in respect of things Divine", MI 251; learning performs two duties and services to faith and religion: "exaltation of the glory of God" and "help and preservative against unbelief and error", AL 222).

Many other texts from Bacon also make use of innovation, in the context of religion and politics. For example, Bacon reminds his readers of both Queen Elizabeth [42] and King James' admonition not to innovate in matters of religion, [43] and he advises Kings, prime

[40] Bacon's representation has been very influential among later writers. To take just one example: echoing, or rather citing Francis Bacon, the *Encyclopédie* suggests that one should only accept innovation "peu à peu & pour ainsi dire insensiblement" (*Encyclopedie*, 1765: 265). "Il est bon de ne pas faire de nouvelles expériences pour accomoder un état sans une extrême nécessité & un avantage visible. Enfin, il faut prendre garde que ce soit le désir éclairé de réformer qui attire le changement, & non pas le désir frivole du changement qui attire la réforme" (*Encyclopedie*, 1765: 266).

[41] Gradualism has precursors among the ancients, to whom change happens over a long period of time, little by little: Isocrate, Aristotle, Plato, Polybius (Edelstein, 1967; Nisbet, 1969). Jeremy Bentham criticizes Bacon's gradualism as a fallacy coming from those against innovation. It is too general because the word innovation is used, according to Bentham, in the sense of restoration (Bentham, 1822: 488).

[42] "Her Publick Admonition in almost every Session of Parliament, that no **Innovation** should be made in the *Discipline* and *Ceremonies* of the *Church*". "Her usuall Custom was, in the beginning of every *Parliament*, to forewarn the *Houses*, not to question, or **innovate**, any thing, already established, in the *Discipline*, or *Rites* of the *Church*" (*The Character of Queen Elizabeth*, 1925).

[43] Bacon advises "that you divide all the Petitions, and the matter therein contained, under several [eight] Heads". The first is religion: Bacon reminds the Duke that "If at any time there shall be the least motion made for **Innovation**" in the Church, he should go back to the "Proclamation set out by the King Himself

ministers and statesmen not to innovate. [44] He also discusses the difficulty of innovating in laws. [45] In two of these texts, Bacon denies innovating himself. He admits innovating only in the sense of restoration: [46] because time corrupts institutions, there is necessity to "restore" the State. [47]

Bacon's idea of innovation did not change over the years. His very first uses of the word were 1589 [48] and 1594, [49] in a political context. The writings produced in the following two decades – professional writings, correspondence as well as philosophical, political and moral essays – carry the same connotation. Among the latter is *Of Innovation*. This

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in the first Year of His Reign, and annexed before the Book of *Common-Prayer*" that "It is most dangerous in a State to give ear to the least alterations in Government". In matter of order and ceremonies, "there must be great care, not to introduce **innovations**" (*A Letter to the Duke of Buckingham*, posthumous).

[44] "Things, I wish to be done. The one, that your Majesty, take this occasion, to redouble unto all your Judges, your antient, and true Charge, and Rule, That you will endure, no **Innovating**, the Point of Juridiction; But will have every Court, empaled, within their own Presidents; And not assume to themselves, new Powers, upon Conceits, and Inventions, of Law" (*A Letter, to the King, concerning the Premunire, in the Kings Bench, against the Chancery*, 1615).

[45] "For the *Lawes*, to make an entire, and perfect, *Union*, it is a Matter of great Difficulty, and Length … How harch, *Changes*, and ***Innovations*** are. And we see, likewise, what Disputation, and Argument, the *Alteration*, of some one *Law* doth cause, and bring forth; How much more, the *Alteration*, of the whole *corps*, of the *Laws*" (*Certain Articles, or Considerations, touching the Union* …, 1603).

[46] In *A Proposal for a New Digest of the Laws of England* (1623), Bacon discusses "Objections and Scruples, that may arise, or be made against" his proposal on the collection of laws. Bacon claims that his proposal "ought not to be termed, or held, an **Innovation** in the suspected Sense … 'tis rather Matter of Order and Explanation, than of Alteration". The same argument is offered in *A proposition, to His Majesty* …, 1616. See below, p. 22.

[47] On imitating foreign churches: "Perhaps in civil States, a Republic is more political than Monarchy; yet God forbid that all lawful Kingdoms should be bound to **innovate**, and make Alterations" (*An Attempt to Promote the Peace of the Church*, 1589) because "it would make a Breach". "*Laws, unrefreshed with new ones, grow sour. And without changing what is bad, the Good cannot be continued … A contentious Retaining of Custom, is as turbulent a thing, as* ***Innovation*** [*novitas*]". There are "two Opinions, which directly confront and oppose all *Reformation in Religion* … The first asserts it to be against good Policy to **innovate** any thing in Church Matters". Yet to Bacon, "custom and usage … are no Warrant to guide and conduct". "All Institutions and Ordinances … corrupt and degenerate". Like time (a "Stream, which carries down fresh and pure Waters into that Dead-Sea of Corruption"), "the *Civil State* should be purged, and restored, by good and wholesome Laws, made every Session of Parliament, devising Remedies … Yet the *Ecclesiastical State* continue … and receive no Alteration at all". Another phrasing appears in *Certain Considerations, touching the better, pacification and edification, of the Church of England* (1603).

[48] "Our *Church* is not now to plant; it is setled, and established. It may be in *Civill States*, a *Republic*, is a better Policy, then a *Kingdom*; Yet *God* forbid, that lawfull *Kingdomes* should tyed to **innovate**, and make Alterations … To be **innovated** ... would make a Breach, upon the Rest" (*An Advertisement, touching the controversies, of the Church, of England*, 1589).

[49] On the physician Roderigo Lopez's treason against her Majesty "to move some ***Innovation*** in *Scotland*", namely to make a party against the Queen, rise arms and levy war (*A True Report* …, 1594). On the "intention of Spain to conquer this Kingdom" by "stir[ring] up by all means a Party ... and desirous of **innovation**, that might adhere to the Forrainer … For this, they had no other Hopes, then the Difference in Religion … Priest were sent into England to plant and disperse a Love to the Romish Religion" (*In Happy memory, of Elizabeth, Queen of England, or, a Collection of the Felicities of Queen Elizabeth*, 1606).

essay continues to discuss innovation as a political concept. In fact, the essay borrows ideas suggested in previous writings: time [50] and medicine [51] as innovators; innovation and the risk of chain reaction (innovating in one thing changes the whole); [52] and gradualism. Let's conclude this section with an early use of gradualism, for gradualism is a perfect example of Bacon's representation of innovation and of how he defends his own innovation.

To Bacon laws are "acts of perpetuity" and it would be a "pitty that the fruit of that Vertue, should dye with you[r Majesty]". In *A proposition to His Majesty ... touching the Compiling, and Amendment, of the Lawes, of England* (1616) Bacon suggests "reducing and recompiling the laws of England". How this should be done? "I speak", writes Bacon, "only by way of perfitting them ... What I shall propound is not to the Matter of the Lawes, but to the Manner" or giving "light" to laws rather "then any new Nature". Then Bacon discusses the "objections or scruples" which may arise against his work. First "the Law, as it is now is in good Estate". To Bacon, the laws are rather "subject to uncertainties and variety of opinion, delayes, and evasions". Also, "there is such an Accumulation of Statutes ... and they do crosse and intricate as the Certainty of Law is lost". The second objection Bacon addresses is: "That is a great **Innovation**. And **Innovations** are dangerous, beyond foresight". To this objection Bacon replies: "All purgings and Medecines, either in the Civile or Naturall Body are **Innovations**. So as that Argument is a Commonplace against all Noble **Reformations**. But the truth is that this work is not to be termed or held for any **Innovation** in the suspected sense. For those are the **Innovations** which are quarelled and spoken against ... But this of General Ordinance pricketh not particulars ... Besides, it is on the favourable part: For it easeth, it presseth

[50] "Two opinions, which do directly confront, and oppose, to Reformation: The one, bringing it ot a Nullity; And the other, to an impossibility. The first is; That it is against good Policy, to **innovate** any Thing, in Church matters ... But ... who knoweth not, that Time, is truly compared, to a Stream, that carrieth down, fresh, and pure Waters, into that salt Sea of Corruption" (*Certain Considerations touching* …, 1604).
[51] "All purgings and Medecines, either in the Civile or Naturall Body are **Innovations**. So as that Argument is a Commonplace against all Noble Reformations" (*A proposition to His Majesty*, 1616).
[52] That the Church of England be "**innovated** ... would make a Breach, upon the Rest" (*An Advertisement, touching the controversies* …, 1589). "For the Lawes, to make an entire, and perfect, Union, it is a Matter of great Difficulty, and Length ... How harsh, Changes and **Innovations** are. And we see, likewise, what Disputation, and Argument, the Alteration of some one Law doth cause, and bring forth; How much more the Alteration of the whole Corps of the Laws" (*Certain Articles, or, Considerations touching the Union of the Kingdomes of England and Scotland*, 1604).

not. And lastly it is rather matter of Order and explanation then of Alteration. Neither is this without President, in former Governments". As examples, Bacon cites the Romans, Athens, Louis XI (France), the emperor Justinian, Henry VIII, Edward VI, Lycurgus, Solon, Ninos ... And he concludes as follows: "I dare not advise to cast the Law into a new Mould. The work which I propound tendeth to proyning and Grafting the Law; and not to plow up and Planting it again: for such a Remove, I should hold indeed for a perillous **Innovation**".

The Age of innovation

Two hundred and fifty years after Bacon, the Swiss biologist Alphonse de Candolle produced a ranking of countries in terms of the number of eminent scientists, using innovation in a positive sense. To Candolle, "les savants anglais auraient … été plus souvent originaux et **novateurs** que les Allemands" (Candolle, 1873: 170). It is to this study that Francis Galton responded, producing his own surveys of men of science in England. A few years later, in a published copy of his thesis to the *Faculté des lettres de Paris*, French professor Victor Egger reminded his readers of the old distinction between *imagination créatrice ou reproductrice* and *mémoire imaginative*. Only the first is productive "**innovation**" and the term imagination should be reserved for it. It "combines" old elements (taken from memory) into a "new whole", a "new order" (Egger, 1881: 191-195).

As Candolle and Egger attest, by the nineteenth century the representation of innovation changes. From a vice until then, innovation shifts to a virtue. This begins gradually between 1750 and 1850, a period that historian Reinhart Kosseleck calls *sattlezeit* (Godin, 2013). Writers start talking of innovation in terms of progress. Science is no exception. While most of the titles on innovation until the nineteenth century come from religion and are produced in England, they now came from many other fields, including science. During the previous centuries, documents of a pamphlet type were the main medium carrying innovation in their titles. Now books, encyclopedias, critical

dictionaries and scientific articles also do so. Most of the titles in science are of French origin (see Table below). Popular magazines are no exception (see Appendix 4).

Table.

Early Titles on Innovation in Science

17th Century

1653 Anonymous, *Défense des nations de France, de Picardie, de Normandie, & d'Allemagne, faussement accusées d'innovations, troubles, entreprises, désordres & confusions par plusieurs Requetes ...*

1668 Casaubon, Meric, *On Credulity and Incredulity in Things Natural, Civil, and Divine … the Use and Necessity of Ancient Learning Against the Innovating Humours, all Along Proved, and Asserted.*

1671 Maynwaring, E., *Praxis medicorum antiqua & nova. The ancient and modern practice of physick examined, stated, and compared …*

1696 Maurin, *Lettre de Mr Maurin, docteur en médecine, à son ami. Par laquelle on connoit les raisons qui ont engagé les Anciens à n'admettre point de Circulation du sang, & celles des Novateurs à se détacher des sentimens des Anciens.*

18th Century

1766 *Encyclopédie*, art. Innovation.

1795 Durtubie, Théodore, *Mémoire et observations sur l'artillerie à cheval, et remarque sur l'Innovation des Machines proposées pour l'équipage de cette artillerie.*

19th Century

1818 *Dictionnaire des sciences médicales*, art. Innovation.

1822 Touchard-Lafosse, G., and F. Roberge, *Dictionnaire chronologique et raisonnée des découvertes, inventions, innovations, perfectionnements, observations nouvelles et importations, en France*.

1829 Cruveilhier, J., *Lésions de l'appareil des sensations et de l'innovation*.

1830 Lanfroy, H., *Au Diable les novateurs!! Ou coup d'œil sur le système d'éducation de J.P. Gasc*.

1835 Winslow, Hubbard, *On the Dangerous Tendency to Innovation and Extremes in Education.*

1836 Octave Delepierre, *Aperçu historique et raisonné des découvertes, inventions, innovations et perfectionnements, en Belgique, dans les sciences, les arts, l'industrie, etc. depuis les Romains.*

1841 Werdet, J., *Innovation. Leçons d'écriture simplifiée*.

1842 Quesneville, Dr., *Précis historique et analytique sur les divers procédés de dorure sans mercure et par immersion; procès auquel cette innovation vient de donner lieu*.

1843 Vannier, H., *La tenue des livres telle qu'on la pratique réellement dans le commerce et dans la banque, ou cours complet de comptabilité commerciale essentiellement pratique et méthodique, et exempt de toute innovation dangereuse*.

1844 Vallee, P. J., *Mémoire sur une innovation apportée au stéthoscope*.

1846 Pélissier, *Essai sur la corrélation des facultés intellectuelles avec l'organisme, suivi de quelques réflexions sur certaines innovations en médecine*.

1854 Raguet de Liman, Louis-Frédéric, *Nouveau cours d'horlogerie avec planches: à l'usage des fabricants et des rhabilleurs: contenant l'explication théorique et pratique de tout ce qu'il faut connaître pour bien fabriquer, repasser, réparer, visiter et régler toutes pièces d'horlogerie ...: suivi de, L'explication des innovations les plus récentes*

1854 Chauvin, F.-L., *Nouveau niveau de pente. Innovations dans les nivellements et instructions pour l'entretien des routes ordinaires*.

1859 Chauvin, F.-L., *Innovation dans la géométrie pratique: nouvel instrument de géométrie appelé polygamètre*.

1860 Dessirier, J.-B., *Symétrie des constructions dans les villes: innovations à ce sujet*.

1861 De Vernois, Prévost., *De la fortification depuis Vauban, ou Examen des principales innovations qui s'y sont introduites depuis la mort de ce grand homme*.

1879 Cresson, A.-J., *Quelques mots sur la construction des maisons d'école et sur le mobilier scolaire. Heureuse innovation dans la construction des tables et sièges*.

1879 Bertier, F., *Simplicité, rapidité, précision. Le genie du tailleur. Innovation d'une méthode de coupe*.

1880 Espanet, Alexis, *Des innovations dangereuses en homéopathie*.

1881 Fleury, M., *Des innovations introduites dans l'enseignement secondaire*.

1881 Balmoussières, J.-B., *Une belle Découverte et une précieuse innovation pour la science et l'humanité, ou la Manière d'enrayer et de guérir à la fois isolément le rhumatisme, la goutte … par la seule action des âtomes d'Ignatia amara*.

1884 Blandenier, A., *Une innovation scolaire et ses conséquences*.

1885 Gosselin, L., *À propos des innovations récentes dans les pansements antiseptiques*.

1885 Cambrelin, A. L., *La fortification de l'avenir. Innovations dans l'art de la fortification, basées sur l'emploi du fer*.

1888 Anonymous, *Innovations métallurgiques intéressant les hommes du fer*.

1889 Anonymous, *Amélioration des écuries de l'armée: nouvelles écuries avec stalles, box et ustensiles métalliques: innovations tendant à empêcher la propagation des maladies contagieuses, supprimer les accidents et diminuer les réparations*.

1893 Boé, F., *De quelques innovations malheureuses apportées ces dernières années aux opérations de cataracte*.

1893 Chevalier, M., *Guérison de la tuberculose de vigne pour servir à l'intelligence du phylloxera devant la Nation. Recueil des plus instructifs pour les Novateurs et spécialement pour les Cultivateurs de toutes catégories.*

1894 Massart, Jean, *La récapitulation et l'innovation en embryologie végétale*.

1895 Bourget, Paul, *À propos d'une innovation à l'Académie française*.

The use of innovation in science (or rather the useful arts, as will become clear to the reader in the next pages) is not due first of all to "pure" scientists. Certainly, one finds thousands of occurrences of the word in the scientific literature, but titles are few. [53] Yet, it is these documents that are the most interesting to intellectual history, for they include full-length discussions of innovation. Titles come from a diversity of people like professors (at different grades), physicians, inventors and military men. Innovation covers medicine, biology, botany, agriculture, accounting, education and the practical arts like warfare, mining, metallurgy, construction and textiles. To the writers, innovation is quite broad, and includes new artefacts (e.g.: machines, artillery, fortresses, furniture), new methods (instruments and processes), [54] new forms of organization (stables) and new practices (education, medicine).

Essentially, innovation has two connotations: a negative and a positive one. There are as many titles which carry one or the other connotation. Innovation is not yet a virtue, although on its way to becoming such. To every writer, innovation is change or novelty, and it is not easy for the analyst to differentiate between the substantive (novelty) and the verb (introducing novelty). In fact, innovation is one of these words with a double meaning: the action and the result or outcome of the action.

Innovation in the negative sense is used for polemical purposes. This use of the concept has a long history, going back to the Reformation at the very least (Godin, 2010; Godin,

[53] At the time, titles are often quite long. They include a detailed description of the document or what we now call an abstract. "Innovation" frequently appears in this abstract rather than in the title.
[54] "Manières" as the French often call them (Balmoussières, 1881; Anonymous, 1888).

2012-13). Three kinds of argument are offered here. One is against tradition and experience or the "danger auquel on s'expose en choquant l'opinion universellement reçue" (Vernois, 1861: 32). One of the very first titles on science is from Mr. Maurin, physician, who wrote against innovators like William Harvey on blood circulation who destroy the principles of the ancients because they rely on experiments "douteux". "Il n'y a rien de plus facile", claims Maurin, "que d'**innover**" (Maurin, 1696: 20). H. Lanfroy, a student of Law in Paris, complains against the "inventeurs de système" who want to reform the universities. The "**novateurs**", says he, "heurte[nt] les opinions reçues et branle[nt] l'édifice de nos vieilles idées" (Lanfroy, 1830: 6).

New sciences too fight against innovators. In a communication to the International Congress of Homoeopathy held in Paris in 1878, doctor Alexis d'Espanet opposes those who innovate in homoeopathy and thus endanger the discipline's progress with "productions stériles ou malfaisantes qui divisent nos forces et tendent à paralyser son essor" (d'Espanet, 1878: 2). "L'homoeopathie lutte avec succès, depuis quelques années, contre les ennemis du dehors", claims d'Espanet. "Elle doit [maintenant] combattre les ennemis du dedans" (d'Espanet, 1878: 15). D'Espanet reviews in turn the innovations in disease treatments, the growing number of medicines and the new ways of making medicines, all made in a spirit of mercantilism (d'Espanet, 1878: 6). Then d'Espanet discusses at length three "inventors" of new practices and medicines. To d'Espanet, "novateur" is a label used to name inventors who do not respect classical science (Hippocrates, Halnemann) introducing "**innovations** excentriques ou funestes ... qui cachent un danger sous les apparences d'un progrès" (d'Espanet, 1878: 14). "Il importe d'affirmer la vérité de l'homoeopathie contre le mensonge, de défendre son intégrité contre les **innovations** dangereuses", "les opinions erronées", "l'illusion et l'erreur" (d'Espanet, 1878: 16).

Yet, one of the most polemical writers is certainly the American Hubbard Winslow, in a talk delivered before the American Institute of Instruction in 1835 (Winslow, 1835: 3-4):

> **Innovation** seems to be the prevailing spirit of our age .... A large portion of the political, civil, and religious world is partaking of it. Ancient dynasties are crumbling; political

> maxims are revoked; venerable authorities are laughed at; established principles are contested; civil institutions are overturned; organized systems and measures, which have survived centuries, are broken up; and the whole framework of society seems to be in a progress of revolution. It is the reaction of an opposite extreme of a past age. [The danger is to] cast away the good … By **innovating** upon doctrines and practices tested by long and wise experience, and by pushing out supposed principles to the extremes of altruism, instead of conducting the human mind steadily forward towards the goal, they [those who sympathize with innovation] will only send it round in a circle of revolution.

To Winslow, there is a middle ground between "radicalism" and tradition: "There is a wise medium between the extremes of servile admiration and a reckless contempt of antiquity. The one prevents the agressive movements of mind ...; the other ... keeps it continually revolving and sinking in a whirlpool of its own independent and furious conceits" (Winslow, 1835: 4-5).

The second argument, already used by Winslow, amounts to a war against or attack on the age or "spirit of innovation". In his work against modern fortifications, *général de division* Prévost de Vernois claims that a professor (Vernois, 1861: 120-22):

> ne se défendra jamais de l'envie d'**innover** et de façonner à sa guise les jeunes têtes qui lui sont confiées; d'introduire des nouveautés qu'il croira de bonne foi être des perfectionnements, et qui pourraient n'être que de grosses bévues … Le **novateur** qui parviendra à introduire quelques changements à nos doctrines aura nécessairement une grande autorité sus ses collègues; car le désir de créer, de passer pour inventeur est une passion très vive … un grand nombre d'ingénieurs sont animés de cette passion.

Similarly, A. Balandier in his case against introducing professional training in public primary schools, claims (Balandier, 1884):

> La soif des **innovations** est un malheur aussi grand que l'incapacité notoire, car elle excite l'ambition et hâte la ruine d'un pays. Perfectionner nos institutions actuelles vaut certes mieux que de tâtonner dans une demi-obscurité à la recherche de la panacée universelle (p. 8). Avant de recommander ou de préconiser une **innovation** il est bon d'en mesurer les conséquences … Le peuple … ne s'est jamais refusé aux réformes urgentes pour peu qu'elles lui aient été démontrées; mais sa sagesse consiste particulièrement en ce qu'il a une peur instinctive des **innovations** à tout propos, lorsqu'une longue expérience n'est pas venue en confirmer la grande utilité … Il vaut dans tous les cas mieux trop de prudence que pas assez. Ce n'est pas s'arrêter dans le chemin du progrès que de ménager ses forces pour éviter une halte forcée (p. 17).

Yet despite this spirit or age of innovation, other writers complain that it has never been so difficult to innovate. In spite of what he calls an "époque d'**innovations**", *colonel* Cambrelin has difficulties, says he, producing inventions because of little support: "on ne se soucie de se préoccuper que d'**innovations** ayant fait leurs preuves" (Cambrelin, 1893: xii). Cambrelin dedicated his work to young engineers, because old ones "ont répugnance et défiance de tous genres de nouveautés" (Cambrelin, 1893: xvii). Similarly, Mallet-Chevalier, inventor, viticulturist and publicist, believes that he has made "un grand pas, en avant, pour arriver à une prompte solution du problème": the *guérison de la tuberculose de la vigne* (Mallet-Chevalier, 1885: 4). "L'erreur de ceux qui font autorité dans le monde savant [est d'avoir] confondu l'effet pour la cause; voilà aussi pourquoi l'ouvrier est si indifférent et rebelle à toute **innovation**, ne croit plus à rien de possible, parce qu'il sait positivement qu'on l'a trompé en haut lieu" (Mallet-Chevalier, 1893: 9).

The third argument used against innovation is making associations or personal attacks on innovators. The attacks are usually launched because of the danger or anticipated consequences of innovation, as the phrase "innovation funeste" suggests (Pélissier, 1846; Fleury, 1881). "Quelle bande de **novateurs**!", wrote Lanfroy about those who want to reform the universities, "Quel tas de charlatans cherche à entraver la marche régulière de nos études classiques" (Lanfroy, 1830: 9). Théodore Durtubie offers a similar accusation in his mémoire on the *artillerie à cheval* (Durtubie, 1795): the inventors or "nouveaux charlatans" forget that "le principe dont ne s'écarte jamais le véritable artilleur, est que dans toutes les machines destinées au service de l'artillerie, on doit toujours dans leurs constructions y trouver *simplicité, solidité, uniformité*". A machine must be "utile sans beaucoup de dépense" too (Durtubie, 1795: 17). "L'expérience est là pour faire justice de toutes **innovations** dangereuses" (Durtubie, 1795: 19). To others, innovators are simply "présomptueux". Vernois wants to "remettre à leur place les **novateurs** présomptueux qui ont réussi à substituer leurs conceptions aux chefs-d'œuvre de notre grand maître [Vauban]" (Vernois, 1861: 7). To physician and professor Pélissier, innovation is a "conspiration universelle et flagrante" (Pélissier, 1846: 75). To still others, like Hippolyte Vannier, whose book on accounting went into many editions and to whom "la loi que

nous nous sommes imposée [est] de ne point **innover**": Innovation is "rêves de théoriciens" (Vannier, 1843: vii).

In contrast, innovation in the positive sense involves two types of arguments. The main one is progress (Godin, 2013). The argument takes the form of discussing innovation in terms of advantage and utility. Echoing Durtubie, Firmin Bertier, *tailleur*, published a treaty on a "méthode de coupe" which received a prize in 1878 at the *Exposition collective ouvrière* for its "simplicité, rapidité, précision" (Bertier, 1879). Inventor F.-L. Chauvin describes his inventions in terms of "advantages" too – a "niveau de pente", more "facile à manoeuvrer" (Chauvin, 1854; 1859). J. Werdet proposes a new method of writing for students, a method of "utilité majeure … qui n'a jamais eu lieu" (Werdet, 1841). P. J. Vallée, Belgian physician, discusses the innovation he brought to the *stéthoscope* which has "pour avantage de réunir en un seul quatre instruments indispensables au médecin" (Vallée, 1844: 112). The innovation offers simplicity to the instrument and makes it mobile. Similarly, Alexis Didacus qualifies his scientific method of gymnastics as an "original **innovation**" which he discusses in terms of utility and advantage (Didacus, 1884). Some others talk of economy of costs (Anonymous, 1889).

Didacus – and Werdet – makes use here of a second type of argument: originality. Innovation is originality in the sense of both origin (being first) and revolutionary, or a major innovation as we say today. Professor Berthier offers this same argument on his "méthode de coupe", making use of the argument at the national (rather than individual) level: "Notre nation étant réputée pour mettre à jour la première toute **innovation** concernant le bon goût, l'habillement ne devait certainement pas rester en arrière de toute autre branche d'industrie et de commerce" (Berthier, 1879:1).

Yet, the first documents carrying the argument for originality in a full-length form are encyclopedias and scientific dictionaries. In the *Dictionnaire chronologique et raisonnée des découvertes, inventions, **innovations**, perfectionnements, observations nouvelles et importations, en France, dans les sciences, la littérature, les arts, l'agriculture, le commerce et l'industrie, de 1789 à la fin de 1820*, Georges Touchard-Lafosse and

François Roberge survey the progress made in science, industry, arts and literature since (Louis XIV and particularly) the French revolution of 1789, and discuss, in a polemical style, the *supériorité* and *suprémacie* of France versus England. How did France get there? “Une impulsion quelconque était attendue; elle fut donnée…Nous avons nommé la révolution” (Touchard-Lafosse and Roberge, 1822: 26). The editors use the term innovation widely, covering both scientific and industrial novelties (metals, agriculture, lighting, textiles, etc.). According to the editors, these industrial innovations – due to the scientific method – brought nothing less than “grandes et salutaires révolutions dans l’économie” (Touchard-Lafosse and Roberge, 1822: 31).

The dictionary is based on (or rather reproduces) about 6,000 “fiches” or “mémoires scientifiques, notices littéraires, et descriptions technologiques” received from as many men of science, men of letters, artists, artisans and industrialists. Sixteen volumes were published between 1822 and 1824. The seventeenth is a table of contents of over 400 pages. Each entry in the dictionary is classified either as invention, innovation, “perfectionnement” (improvement), new observation or importation. The latter category includes “brevets d’importation” and many products from agriculture (seeds, plants, etc.). It is introduced in order to show the readers the (few) novelties that are not original, namely not of French origin. *Invention* refers to machines and instruments, particularly those that are patented. *Perfectionnement* refers to improvements in machines, or what we call “minor” innovations today. *Innovation*, never defined as such, is what is considered by the editors as original or revolutionary novelty. It covers scientific, technical as well as *arts et lettres* and industrial novelties. *New observation* is essentially scientific discoveries.

The other encyclopedia carrying innovation in its title is Octave Delepierre’s *Aperçu historique et raisonné des découvertes, inventions, **innovations** et perfectionnements, en Belgique, dans les sciences, les arts, l’industrie, etc. depuis les Romains*, published in 1836 in Belgium. In over 200 pages, Delepierre surveys “les hommes et les choses remarquables de la Belgique” in industry, agriculture, fine arts, letters and science. The author makes use of the concept within a national perspective again. His aim is to “faire

voir combien les Belges en toutes choses ont constamment été en progrès, et très souvent même, ont donné l'impulsion aux autres nations" (Delepierre, 1836: 5). In spite of the word innovation in the title, this is an example of a work which does not really make use of the word as a substantial concept. Delepierre uses the word only a few times in the text (Delepierre, 1836: 14, 55, 69, 141). To Delepierre, innovation is a new invention or the introduction of an invention (novelty) for the first time (originality).

Finally, a dictionary deserves mention because it introduces a classification of innovations. The article (entitled **Innovation**) is perhaps the very first title carrying a positive meaning of innovation (*Dictionnaire des sciences médicales*, 1818). To the author, innovation is either bad (speculation) or good (practical). The author of the article develops a reflection on the "mot **innovation** appliqué à la médecine". He surveys the history of medicine, from speculation to facts and asks: "Comment se fait-il que l'art de guérir voit ses théories et ses méthodes changer tous les jours?"

> La médecine, dit-on, a changé et change encore tous les jours; chaque siècle, et souvent des périodes moins longues voient proclamer, proscrire et renaître des méthodes de traitement diamétralement opposées. A quels traits peut-on distinguer une **innovation** dangereuse? Quelle est la marque d'un changement amené par les progrès réels de la science? Comment distinguera-t-on les produits d'une imagination capricieuse d'avec les résultats d'une sage expérience" … [Answer:] le sentier pénible de l'observation; c'est en partant de ce point essentiel, que les physiologistes modernes ont provoqué, non des **innovations** mais de véritables progrès dans l'histoire de notre économie" (p. 248-49).

To the author, an innovation is "dangerous" when it is introduced "non en vertu d'une observation rigoureuse, mais par le seul effet de théories funestes" (*Dictionnaire des sciences médicales*, 1818: 251). All in all there are three classes of innovations: "les **innovations** produites par l'esprit de système", "les **innovations** qui sont le résultat d'une observation plus attentive et de faits mieux étudiés" and "les **innovations** venues de procédés perfectionnés, de remèdes introduits, de pratiques adoptées" (*Dictionnaire des sciences médicales*, 1818: 254-55). "Espérons ... que les **innovations** dont la science sera toujours possible, dont elle éprouvera même un constant besoin, soient désormais dirigés vers la pratique" [traitement des maladies et méthodes cliniques] (*Dictionnaire des sciences médicales*, 1818: 244).

One important group of titles on innovation in science in the nineteenth century is the continuation of the seventeenth-eighteenth century *querelle* between the ancients and the moderns. Lanfroy (1830), Pélissier (1846), and Fleury (1881) are concerned, among other things, with the danger of innovating practices in education *versus* preserving the traditions, namely against the introduction of the sciences in place of teaching Greek and Latin. In turn, Winslow puts emphasis on the introduction of physical education to the detriment of intellectual education. [55] In matters intellectual, Winslow objects to 1) the introduction of what he calls ”devices to avoid severe study”, namely “modern adaptation of books” which render them “cut and dried”, too easy to read and made for pleasure, and 2) teaching methods (“visible signs, plates, figures, machines”) which neglect the work of the imagination (Winslow, 1835: 13-14).

One conclusion from the above sample is the relative absence of discussion on innovation and industry in the nineteenth century – in contrast to the discourses on the mechanical arts or technology and applied science (Bud, 2012; Schatzberg, 2012) –, as well as explicit reference to manufacturing. At the time, innovation had little to do with market issues, as many study innovation today. There are only three documents covering industry. Yet two of these – the encyclopedia of Touchard-Lafosse and Roberge and that of Delepierre – include many things under the concept innovation. Innovation is not exclusively concerned with industry. The third title comes from Doctor Quesneville on a British patent on a “procédé de dorure” (Quesneville, 1842). The French author deplores that the “**innovation** qui était appelée à produire une revolution” has not delivered its promises. Quesneville claims that if the demand for a patent is accepted in France it may endanger trade.

To be sure, there exist dozens of documents in the nineteenth century in which innovation is used, in a positive sense, to talk about what we call “technology” today. Mining,

[55] “… there are two “callings”, either physical or intellectual: “physical perfection is not essential to mental eminence” (Winslow, 1835: 6-7). As evidence, Winslow suggests that all great scholars from Antiquity to modern authors “have been men of rather slender physical development or of some bodily infirmity” while “those students who bear the palm in gymnastic exercises, are usually the poorest scholars” and “seldom eminently intellectual” (Winslow, 1835: 8). The “professional student … rose early in the morning, they ate late, slept little, thought much” (Winslow, 1835: 9). He “avoids notions and extremes, think as little of his body as possible” (Winslow, 1835: 10).

particularly, is an example (Blavier, 1806; 1812; Villefosse, 1820). Auguste Comte too talks of the invention of printing as an "innovation capitale" (Comte, 1877: 114). Yet, technological innovation is only one of the many connotations of innovation. Innovation had not yet acquired the restricted and dominant connotation of the twentieth century (technology). [56]

In summary, innovation in nineteenth-century science refers to the introduction (application) of the scientific method in useful arts: professional and, to a certain extent, industrial. [57] There is no title on innovation in the "pure" sciences like physics, mathematics or astronomy. [58] In the other sciences like medicine, innovation means essentially new scientific instruments. [59] In education, innovation is essentially negative (new practices).

Two elements characterize innovation. First, utility – as opposed to the theoretical, as the *Dictionnaire medical* puts it. Accountant Vannier, for example, qualifies his new method as "practical". The anonymous work on metallurgy claims that "La plupart [des ouvrages traitant les diverses manières d'employer les fers et les aciers] sont faits par de savants théoriciens qui ne donnent que des définitions au lieu de procédés pratiques"

[56] A different but then newly-coined term serves to talk of technological innovation: technology. Jacob Bigelow, Jacob Beckman and Charles Babbage, to name just the most studied writers of the nineteenth century on technology, as well as dictionaries of techniques, arts and manufacture, make no use of innovation in the positive sense.

[57] This is close to the French meaning of *science appliquée* (*à l'industrie*) (Bud, 2012).

[58] A few exceptions are: Land (1876), Heaviside (1893), Knott (1893).

[59] One different use deserves mention. In *La récapitulation et l'**innovation** en embryologie végétale*, botanist Jean Massart from *Université de Bruxelles* discusses evolution and the principle of recapitulation or how the development cycle of the individual (*ontogénèse*) is an abridgement of that of the species (*phylogénie*). Yet, an individual also develops new organs "dont ses ancètres étaient dépourvus" (Massart, 1894: 4). To Massart, such an innovation is more frequent in plants: "chaque année, un frène forme de nouvelles racines, de nouveaux bourgeons, de nouvelles fleurs" (Massart, 1894: 4). Innovation is a word used in botany before Massart, namely for the "organes de fécondation" de la mousse *Webera annotina Schwaegr* qui apparaissent et se développent sur les feuilles et les tiges des plantes. Elles "constituent [produisent] de nouvelles tiges qui remplacent la première et se comportent comme elle l'année suivante … et produisent, avant de mourir, des **innovations**" (Bescherelle, 1865: 138). The *Dictionnaire de la langue française* from Émile Littré (1872-77) acknowledges this meaning as follows: "Terme de botanique applicable à la ramification des hépatiques (cryptogames) caulescentes. L'innovation est la continuation de la tige par le développement d'un bourgeon". The *Oxford English Dictionary* (1989) translates as follows: "the formation of a new shoot at the apex of a stem or branch; esp. that which takes place at the apex of the thallus or leaf-bearing stem of mosses, the older parts dying off behind; also a new shoot thus formed".

(Anonymous, 1888: préface). Second, the practical rest or should rest on scientific principles. Vallée contrasts the principles of the ancients to "positive medicine", on which his innovation on the stethoscope rests. Raguet de Liman (1854) stresses the need for "sciences positives" in clock-making. [60] Didacus describes his teaching (of gymnastics) as "rationnel et méthodique", namely based on anatomy and physiology. Touchard-Lafosse and Roberge attribute industrial innovations to the scientific method.

Yet in the end one must conclude that the pejorative connotation of innovation is only beginning to change. There is still an ambivalent tension between the negative and the positive. The use of the concept in the negative simply continues the tradition of the previous centuries: a linguistic weapon. In contrast, the use in a positive sense is due to many factors (Godin, 2013): a changing context (change is now accepted in every sphere of society); efforts to increase the social status of the arts (as the word "technology" does; see Schatzberg, 2006); and the value put on originality: stressing one's own originality or that of his country for their contribution to "progress".

Conclusion

The representation of innovation has changed considerably since the seventeenth century. To Bacon and his contemporaries novelty is everywhere – to the point that it is often qualified as ephemeral and frivolous. Yet innovation is forbidden. This moment of history when innovation was pejorative because it was a political concept is a forgotten episode today. Over the twentieth century, innovation has shifted to technological innovation in a positive sense, as the dominant ideology. [61]

Bacon's innovation (a new scientific method) or rather the introduction of a new scientific method into the useful arts in the nineteenth century is one of the factors that gave a positive meaning to the concept innovation. From the late eighteenth century

[60] Clock-making requires "connaissances très-étendues des sciences positives" (p. i). However, too foten, "les principes sont négligés, les apprentis pullulent chez des maîtres ignorants" and "des montres de pacotille vendues à vil prix et sans la moindre garantie" substitute clock-making (p. ii).
[61] Interestingly, the same shift in meaning happened to invention in Bacon's time (see Appendix 3).

innovation is talked of in terms of utility and the useful arts are part of this new discourse. The useful arts also contributed to one if not the dominant meaning of innovation today, linking science to (technological) innovation. Here is the origin of the intimate association between science, technology and technology.

Over the twentieth century, industry and economics (together with management and policy) appropriates the word innovation…and the concept. One may observe here an analogy (or extrapolation) between the early meaning of the concept (*introduction* of the scientific method into the useful arts) and modern uses of "technological innovation" (invention or science *applied* to industry). [62] Yet, one missing connotation in the early definition of the concept is the market, or commercialization. We have seen that few authors make explicit reference to industry in the nineteenth century. In contrast, the representation of innovation developed over the last sixty-five years focuses on technological goods, firms and markets. The two representations may be contrasted, but they are also evolving representations of innovation in the sense that one develops (extends) from the other, as a consequence of a new context. The definition, or rather connotation of innovation as the introduction of the scientific method into useful arts (the 'scientification' of the arts) shifts to the application of invention or science to industry (the 'scientification' of industrial production).

The social sciences are the link here. To the early theorists of innovation, technological innovation is the application of science or scientific knowledge to industry. Certainly, industrialists have talked of the industrial laboratory in these terms since the late nineteenth century, but without the term innovation. Certainly too, (some) engineers (together with chemists and physicians) started making use of the word innovation in the early twentieth century to name their inventions. To the engineers of the time, innovation is machines for industrial production, but also new or improved instruments and devices for the sciences and the professions. Yet, it is the post-World War II social scientists that started studying innovation in the sense of "science applied" to industry (a concept

[62] Application of science to industry refers to both the *scientific method* (through the setting up of industrial R&D laboratories) and the *results* of science (use of scientific discoveries and inventions).

different from applied research). Technological innovation is the application or implementation or transformation of science into new technological products/processes (Godin, 2014b). [63]

Table

Innovation According to Fields

Useful Arts

Introduction of the *scientific* method

Engineering

New 'machines' for *industrial* production and instruments/devices for the *sciences* and the *professions*

Social Sciences

Technological innovation: application of science to industry

In recent years, historians have started to study the semantics of diverse concepts of science: natural science (Phillips, 2012), basic science (Clarke, 2010), applied science (Bud, 2012), technology (Schatzberg, 2006; 2012). The present paper adds one more concept to the list: innovation. Over time, technological innovation has become a super-category, encompassing or replacing previous concepts in discourses – and theories:

[63] The social researchers invented a classification of technological innovations as either process or product innovations. Process innovation is technological innovation for use in industrial production. This gave rise to a tradition of research among neo-classical economists known as "technological change" (the study of changes in the factors of production). To the process category, non-mainstream economists added a category of their own: "product" innovation as innovation for the consumer market (i.e.: commercialized). Historians of technology frequently suggest that technology has shifted its meaning from *technique* to artifact over the nineteenth and twentieth centuries (Morère, 1966; Guillerme and Sebestik, 1968; Salomon, 1984; Marx, 1997; Schatzberg, 2006). In turn, technological innovation merges the two meanings (talked of in terms of processes and products) into a unifying and encompassing concept.

(Useful) Arts

↓

Applied Science

↓

Technology

↓

Technological Innovation

In the end, technological innovation is a sociological concept. While the concept of basic research (pure research, fundamental research) originates from natural scientists (Kline, 1995; Lucier, 2012) technological innovation comes from social researchers. What the social theorists of the twentieth century – in collaboration with governments by the way – have brought to the study of innovation is the contribution of technological innovation to national economic growth. This has been very influential as a *rationale* for the development of policy to stimulate technological innovation. In turn, policy has been influential in transforming the concept innovation into a popular one over recent decades. While technology, as Eric Schatzberg puts it, "helped raise the useful arts above the world of grubby artisans and into the spheres of big business and the university" (Schatzberg, 2006: 487), technological innovation has put innovation on the policy agenda...and much more. Innovation has become a *supercategory*, to use Ron Harris' term: it "integrates what would otherwise be separate activities and inquiries" in order to redraw the intellectual world that society adopts (Harris, 2005: xi).

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Appendix 1.

Bacon's Essay *Of Innovation*
1625

As the births of living creatures, at first are ill-shapen so are all innovations, which are the births of time. Yet notwithstanding, as those that first bring honor into their family, are commonly more worthy than most that succeed, so the first precedent (if it be good) is seldom attained by imitation. For ill, to man's nature, as it stands perverted, hath a natural motion, strongest in continuance; but good, as a forced motion, strongest at first. Surely every medicine is an innovation; and he that will not apply new remedies, must expect new evils; for time is the greatest innovator; and if time of course alter things to the worse, and wisdom and counsel shall not alter them to the better, what shall be the end? It is true, that what is settled by custom, though it be not good, yet at least it is fit; and those things which have long gone together, are, as it were, confederate within themselves; whereas new things piece not so well; but though they help by their utility, yet they trouble by their inconformity. Besides, they are like strangers; more admired, and less favored. All this is true, if time stood still; which contrariwise moveth so round, that a froward retention of custom, is as turbulent a thing as an innovation; and they that reverence too much old times, are but a scorn to the new. It were good, therefore, that men in their innovations would follow the example of time itself; which indeed innovateth greatly, but quietly, by degrees scarce to be perceived. For otherwise, whatsoever is new is unlooked for; and ever it mends some, and pairs others; and he that holpen, takes it for a fortune, and thanks the time; and he that is hurt, for a wrong, and imputeth it to the author. It is good also, not to try experiments in states, except the necessity be urgent, or the utility evident; and well to beware, that it be the reformation, that draweth on the change, and not the desire of change, that pretendeth the reformation. And lastly, that the novelty, though it be not rejected, yet be held for a suspect; and, as the Scripture saith, that we make a stand upon the ancient way, and then look about us, and discover what is the straight and right way, and so to walk in it.

Appendix 2.

Bacon's Commonplaces on Innovation

For.	Against.
Every medicine is an innovation.	Things new born are ill-shapen.
He that will not have new remedies will have new evils.	The only author I like is time.
Time is the greatest innovator, why then should we not imitate time?	There is no novelty that does not some hurt, for it unsettles what is.
Ancient precedents are unfit, modern ones corrupt and interested.	Things settled by custom, though they be not good, yet at least they fit one with another.
Leave it to the unskilful and the contentious to act by precedent.	What innovator imitates time, who so insinuates his innovations that they are not perceived?
As those who first bring honour into their family are commonly worthier than their descendants, so are the first precedents commonly better than the imitations of them.	That which comes unlooked for gets the less thanks from him whom it helps, and gives the more annoyance to him whom it hurts.
A froward retention of custom is as turbulent a thing as an innovation.	
Seeing that things alter of themselves to the worse, if counsel shall not alter them to the better, what shall be the end?	
The slaves of custom are the sport of time.	

Appendix 3.

Bacon on Invention

In *The Advancement of Learning*, Bacon distinguishes two kinds of invention: invention in sciences and arts, and invention in rhetoric (AL 219). Up to then, the latter was the common meaning of what invention is: a step to bringing forth good arguments. As Bacon put it, invention "draw[s] forth or call[s] before us that which may be pertinent to the purpose which we take into our consideration" (AL 223). However, to Bacon such invention "is not properly an invention for to invent is to discover that we know not, and not to recover or resummon that which we already know" (AL 222-23). Although it may serve to "direct inquiry" and for "wise interrogating", it is not invention but memory (AL 224).

To Bacon, real invention is invention relative to science and art. To Lord Verulam we owe this new definition of invention, or rather its later diffusion (as matter of fact, Bacon was taking note of an increasing use of the term invention in "technological" or arts matters). [64] However, this kind of invention is actually "deficient" according to Bacon. It relies on chance rather than reason, and on a form of induction which is "vicious and incompetent". *Novum Organum* is entirely concerned with this kind of invention and its division between *experience literara* and *interpretatio naturae*. In this work Bacon offers a systematic method for invention in science and arts.

One may ask to what extent Bacon's view has contributed to the modern representation of invention as technological invention. In Bacon's time, invention meant finding (discovery) as well as making (construction, fabrication) and was applied, generally with few qualifications, to both activities. Later, a distinction was made between two concepts: discovery refers to facts or things that already exist out there and that one finds out, while invention combines and makes new things (Wyman, 1929; Kneale, 1955). Discovery is reserved for science, and invention for arts. Today, to many people, invention relates to

[64] See Long (2001) for many quotations using the word invention in very old books and treaties on "technology". On the concept of invention in the context of technology in the seventeenth and eighteenth centuries, see Macleod (1988). On the history of the concept of technology, see Schatzberg (2006).

technology. The twentieth century is witness to a similar change in the meaning of innovation.

Appendix 4.

Popular Magazines

1836 Le Novateur, journal médical

1839 Revue des spécialités et des innovations médicales et chirurgicales.

1850 L'innovateur, journal des cordonnier-bottiers (then: Le moniteur de la coordonnerie in 1860; an English edition beginning in 1857: The Innovator or Boot-and-Shoemaker's Monitor).

1854 Journal des novateurs dans l'industrie, les sciences, les lettres et les arts.

1862 L'innovateur, revue industrielle et commerciale de la carrosserie.

1881 Le novateur financier.

1881 Le novateur littéraire.

1884 Le novateur.

1890 Le Novateur, journal des inventions pratiques.

1896 L'innovateur médical, journal de médecine et de chirurgie.

1897 L'oeuvre du siècle. Inventions, progrès, innovation (then Arts, sciences, agriculture ... in ????).

1901 Le vulgarisateur des innovations agricoles, organe trimestriel des intérêts agricoles, viticoles du potager et du verger.

1901 L'innovation, journal coopératif bi-mensuel (then Revue encyclopédique des connaissances utiles, littéraires et scientifiques in ????).

1902 L'innovation, journal commercial et industriel.

1908 Journal innovateur: commercial et littéraire.

1919 L'innovateur, chronique du nouveau.