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Broad Concerns about Nanotechnology Patents: Symptoms and Diagnosis

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Abstract

We discuss the concerns that the patenting activity in the new nanotechnologies could blur the line between what is considered a discovery and what can be considered as an invention. We find that the nature of nanotechnology products, research, and the development agendas in science and engineering fields that include biomimetics pose a challenge to the present practice of including chemicals as eligible patent subject matter. After revisiting the historical development of patent law and noting its divergence from the developments in science and technology, we introduce the distinction between simple and complex machines as these relate to chemistry and nanotechnology. This distinction poses the question of what is the logical category of inventions that fall within patentable subject matter given that patent law was conceived to cover simple machines, not complex ones.

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29/06/2012 15:13

Contents

I. Symptoms

The business excitement about nanotechnology[1] is reflected by aggressive and intensive patenting strategies pursued by private and public entities attempting to stake a claim. Concurrent with this excitement are the many concerns about nanotechnology patents aired across a variety of publications ranging from law reviews to reports by non-governmental organizations (NGOs).[2] At the European Union (EU) level, the question was asked "when is a nano-object a natural object (and thus not patentable) and when is it a constructed object?"[3] This report also cites the work of the Action Group on Erosion, Technology and Concentration (ETC) and its claim that "the general doctrine in patent law, that products of nature cannot be patented, can be sidestepped because of the atomically engineered building techniques." In addition, it reports on a seminar organized in 2003 at the European Parliament by a coalition including the ETC and the Green party where the concern is voiced that "one fundamental nano-patent might dominate developments in many industrial sectors, and enable the ownership of nature."[4] Another concern was formulated pertaining to the products of nanotechnology as "the progressive blurring of the invention/discovery interface under Article 27 TRIPS that may produce uncertainty over the types of nanoproducts that can be patented." [5] The same commentator further contends that a "wide interpretation of that Article 27(1) may result in the monopolisation of fundamental molecules and compounds."[6]

However the concerns about the erosion of the invention–discovery distinction as a foundational principle in patent law are older than the buzz about nanotechnologies and nanomaterials. At the turn of the millennium, the general concern was voiced that "the old distinction between discovery and invention, the foundation of the patent system, has been obliterated."[7] In particular, "[n]ot merely are life-forms being

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[1] We prefer the term 'nanotechnologies' over 'nanotechnology' to address the issues raised in the literature. In this paper we will however use the most appropriate of the two within the scope of the discourse or argument. Other terms used are nano-object, nano-patent, and nano-specific, all of which refer to physical, immaterial or tacit objects.

[2] ETC, *Nanotech "Second Nature" Patents: Implications for the Global South*, 2005, retrieved 5. 5. 2011, <http://www.etcgroup.org/en/node/54>; ETC, *The Big Downturn? Nanogeopolitics*, 2010, retrieved 5. 5. 2011, <http://www.etcgroup.org/en/node/5245>; I Barpujari, 'The Patent Regime and Nanotechnology: Issues and Challenges', *Journal of Intellectual Property Rights* vol. 15, 2010, pp. 206-213.

[3] 4th Nanoforum Report: Benefits, Risks, Ethical, Legal and Social Aspects of Nanotechnology. Part 7: the need for and rise of new legislation and regulation caused by the emergency of Nanotechnology, 2nd Edition, October 2005: 244; all Nanoforum reports are available from the website http://www.nanoforum.org/.

[4] TA Phelps, 'The European Approach to Nanoregulation', *Nanoscale: Issues and Perspectives for the Nano Century* 2007, pp. 189-210.

[5] DM Bowman, 'Patently obvious: Intellectual property rights and nanotechnology', *Technology in Society* vol. 29, 2007, pp. 307-315.

[6] Ibid.

[7] GC Gallopín, S Funtowicz, M O' Connor, & J Ravetz, 'Science for the twenty-first century: from social contract to the scientific core', *International Social Science Journal* vol. 53, no. 168,

patented wholesale, but the identification of a possible function for a DNA sequence is sufficient for it to count as an 'invention', the property of he/she who stakes claim to it."[8] Speculation is running high on the problems that will arise from the patenting of nanotechnologies, and the proposed solutions take many forms.[9] In addition, one early commentator listed potential utility problems that would arise from interdisciplinarity, inoperability, practical-utility, and upstream research.[10] Another commentator, motivated by the investigation of the broad patenting of nanomaterials, also proposes the adoption of a strict utility requirement as the solution to the alleged tragedy of the anticommons in US nanotechnology.[11] Yet another concern arises in light of the [US] Federal circuit's decision in *Madey v. Duke University*,[12] which narrows the scope of the experimental use defence to patent infringement, and thus is perceived to further stifle nanotechnology innovation.[13]

In view of the potential seriousness and dire consequences for the public good expressed by these broad concerns over the ownership of nature and in terms of the invention–discovery dichotomy recapitulated above, we revisit patentable subject matter evolution from the perspective afforded by nanotechnology in general, and patent law in particular. We also keep in mind the ubiquitous convergence across all fields of science and technology[14] – physical science, chemistry, biotechnology, systems biology, information and cognitive sciences – all contributing to the emerging nanotechnologies, which also blurs the line between science and technology.[15]

In this paper we address these broad concerns about nanotechnology's atomically engineered prowess and elaborate the question of the presumed blurring of the invention–discovery interface under Article 27 of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). For this purpose we first take a

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2001, pp. 219-229. The concern is voiced in the context of addressing the need posed by the challenges of sustainable development and the changing contexts at the beginning of the twenty-first century that bring with them changes in the method and practice of science, which in turn require changes in scientific methods, criteria of truth and quality, and conceptual frameworks.

[8] Ibid. 7.

[9] McLennan and Rimmer recently surveyed the many challenges posed by nanotechnology to patent law, policy and practice : A McLennan, & M Rimmer, 'Cosmo, Cosmolino: patent law and nanotechnology' in M Rimmer, & A McLennan (eds.), *Intellectual Property and Emerging Technologies: The New Biology*, Edward Elgar Pub, 2012, pp. 255-290.

[10] DS Almeling, 'Patenting Nanotechnology: Problems with the Utility Requirement', *Stanford Technology Law Review* vol. N1, 2004, pp. 1-22.

[11] Reynolds, G, *Nanotechnology and the Tragedy of the Anticommons: Towards a Strict Utility Requirement*, 2009, retrieved 16. 02 2012, <http://www.uoltj.ca/articles/vol6.1-2/2009.6.1-2.uoltj.Reynolds.79-114.pdf>.

[12] *Madey v. Duke University*, 307 F.3d 1351 (Fed. Cir. 2002).

[13] NM Zovko, 'Nanotechnology and the Experimental Use Defense to Patent Infringement', *McGeorge Law Review* vol. 37, 2006, pp. 129-156; W Helwegen, 'The research exemption from a nanotechnology perspective', *European Intellectual Property Review* vol. 327, 2010, pp. 341-351.

[14] WS Bainbridge, & MC Roco, 'Reality of Rapid Convergence', *Annals of the New York Academy of Sciences* vol. 1093, no. 1, 2006, pp. ix-xiv.

[15] We note that the requirements for an invention in patent law from a UK and EPC perspective have been dealt with in great detail recently in: Pila, J, The Requirement for an Invention in Patent Law, Oxford University Press, USA, 2010.

different tack towards clarifying what *nanotechnology* is: nothing new. We argue that the so-called nanotechnologies are governed by the non-intuitive quantum mechanics that also governs chemical bonding, the convergence process in the sciences and technology, and introduce the distinction between simple and complex machines to guide the transition from classical to quantum mechanics within the context of technology patents in section II. In section III we survey the overall patenting activity in nanotechnology and discuss specific examples of patents involving carbon allotropes, self-assembling peptides, and mechanosynthesis of carbon. In the same section we also address the issue of size as it pertains to nanotechnology patents and patent disputes involving nanotechnology. In section IV we turn to the area of technology that is most intimately related to nanotechnology, that is, chemistry, its ontology and meandering history through the patent system. Finally, in section V, we establish that behind these ill-justified concerns lies a bigger problem, that of what constitutes chemical invention.

II. Nature of Nanotechnology

Nanotechnologies are both emerging and enabling.[16] Nanotechnologies have elements of chemistry, physics, engineering, and smoothly cross over to biology and biotechnology, thus blurring classical twentieth century disciplinary boundaries. The disciplinary location of nanotechnology is complex and challenges the predominant reductionism that characterizes most classical disciplines.[17] We note that nanotechnology as a discipline has been questioned, and what is observed is that "most scientists remain close to their original disciplines."[18] The issue of the often alluded convergence is not in the disciplines themselves, it is one of methods[19] but also in the aggregation of disciplines in technology clusters.[20] Above all, the nanotechnologies exploit effects that can be explained within the theory of quantum

[16] See for example: Baird, D, A Nordmann, & J Schummer, Discovering the nanoscale, IOS Press, 2004; D Baird, & T Vogt, 'Societal and ethical interactions with nanotechnology "SEIN" - An Introduction', *Nanotechnology Law & Business* vol. 1, no. 4, 2004, pp. 391-396; Schummer, J, & D Baird, Nanotechnology Challenges: Implications for Philosophy, Ethics and Society, World Scientific Publishing Company, 2006; Bainbridge, WS, Nanoconvergence: the unity of nanoscience, biotechnology, information technology, and cognitive science, Prentice-Hall, 2007.

[17] Roco, MC, & WS Bainbridge, Societal implications of nanoscience and nanotechnology, Kluwer Academic Publishers, 2001; Roco, M, & W Bainbridge, Converging technologies for improving human performance: Nanotechnology, biotechnology, information science and cognitive science, 2003; S Loeve, 'About a Definition of Nano: How to Articulate Nano and Technology?', *Hyle - Internantional Journal for Philosophy of Chemistry* vol. 16, no. 1, 2010, pp. 3-18.

[18] V Mangematin, & S Walsh, 'The future of nanotechnologies', *Technovation* vol. 32, no. 3-4, 2012, pp. 157-160.

[19] Speaks of a nanotechnological approach (method) in pharmaceutical technology: N Daum, C Tscheka, A Neumeyer, & M Schneider, 'Novel approaches for drug delivery systems in nanomedicine: effects of particle design and shape', *Wiley Interdisciplinary Reviews: Nanomedicine and Nanobiotechnology* vol. 4, no. 1, 2012, pp. 52-65. Biology inspired engineering: T Jovanovic-Talisman, & A Zilman, 'Nanobiotechnology: building a basic nanomachine.', *Nature Nanotechnology* vol. 6, no. 7, 2011, pp. 397-398.

[20] N Battard, 'Convergence and multidisciplinarity in nanotechnology: Laboratories as technological hubs', *Technovation* vol. 32, no. 3-4, 2012, pp. 234-244.

mechanics and that are often attributed to particle size.[21] Nanotechnology, the umbrella term for all nanotechnologies, has elements of both science and technology. As such it is both an area of rapid scientific discovery, and one of accelerated technological development. Nanotechnology involves engineering at the quantum level, and immersion into scientific fields that defy common intuition. Much has been written on its nature; however, when one gets down to the bare bones of the issues that deal with nanomaterials, it is fundamentally chemistry. Chemistry is also a service science that can be applied in many technological fields. Another view is that "nanotechnology is only one potential future for chemistry."[22] And, taking a more informed view "a number of research pathways developed over the last decades of the twentieth century – catalysis, supramolecular chemistry, biomimetic chemistry, soft chemistry, etc. – paved the way for nanotechnology and are sometimes relabeled nanochemistry."[23]

A. *Engineering at the Quantum Level*

Nanotechnology could be described as engineering at the quantum regime, but then, engineering at the quantum regime is exactly what chemistry has been all along. This regime, also known as quantum physics[24] is the realm of the Planck scale (time, length, mass, energy, etc.), that is, the regime of the very small in all physical dimensions. At the Planck scale[25] the common-sense intuitive concepts of size and distance break down. It is also not that the quantum scale gets turned off in macroscopic objects; it is just that the quantum scale effects dominate at the microscopic level.[26] It can be said that the quantum physical regime is described by probability distributions of the set of outcomes of measurements of an observable. This apparent indeterminacy in quantum systems has nothing to do with errors of measurement, it is of a much more fundamental nature. However, this is also an area of physical theory that challenges human concepts of logic and intuition which make up a considerable part of reasoning used for establishing the degree of obviousness.[27] At the risk of labouring the point, the non-obviousness nature of quantum phenomena

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[21] Nanoparticle definition 10–200 nm or whatever is most often cited. However there is no generally agreed definition of nanotechnology based on size. For a recent discussion on the definition see: G Liden, 'The European commission tries to define nanomaterials.', *Ann Occup Hyg* vol. 55, no. 1, 2011, pp. 1-5. In addition, the European Commission has recently issued recommendations on the definition of nanomaterial that include size considerations: [2011] OJ 275/38.

[22] Bensaude-Vincent, B, *Boundary Issues in Bionanotechnology: Editorial Introduction*, retrieved 12. 3. 2012, <http://www.hyle.org/journal/issues/15-1/editorial_bensaude.htm>.

[23] Ibid.

[24] Physics is inclusive of chemistry although traditionally chemistry is not considered a sub-division or sub-discipline of physics. The fact is that to gain expert knowledge of chemistry, a student must become well versed in the prevalent theories of physics, in particular quantum mechanics. Thus the term "quantum physics" is broader and includes chemistry.

[25] The Planck scale can refer to either a length scale or a time scale, the two being related by the uncertainty principle formulated by Werner Heisenberg.

[26] V Verdal, 'Living in a Quantum World', *Scientific American* vol. 304, 2011, pp. 38-43.

[27] In the EPO Guidelines C-IV, 11.4 it is stated that "[t]he term 'obvious' means that which does not go beyond the normal progress of technology but merely follows plainly or logically from the prior art, i.e. something which does not involve the exercise of any skill or ability beyond that to be expected of the person skilled in the art."

cannot be ignored in a discussion of what constitutes patentable subject matter in general, and invention in particular. This quirk of nature ought not to be an excuse to consider any scientific discovery in this field an invention because of its non-obviousness. There is often much confusion in the literature between discovery and non-obviousness but they are two different concepts belonging to different aspects in patent law. Discovery pertains to patentable subject matter, and the question of obviousness pertains to the inventive step or inventiveness. Still, the take home lesson here is not about the relationship between discovery and obviousness. The take home lesson ought to be that Nature's quantum manifestations are ludicrous,[28] and thus not accessible to the so-called common sense, which social and legal scholars are fond of invoking. In other words "[i]t is perhaps not surprising that, at small scales, things behave in strange and counterintuitive ways; after all, our intuitions have developed for dealing with objects much larger than individual atoms."[29] That is, in order to clarify the legal and policy issues, one is well advised not to mix up what the fundamental nature of the technical substance is with what the theoretical, legal and philosophical issues relevant for policy are.

1. *Convergence*

Not only have nanotechnologies been made possible by the convergence of several disciplines through the use of related methodologies, nanotechnologies are also in their nature intimately related to chemistry. The nanoscale is the scale at which chemistry takes place. The discipline of chemistry was preceded by alchemy, the goal of which was the transformation of ordinary matter into gold. In a metaphoric sense, material technologists today have achieved this goal. Today materials science and technology allows for the engineered creation of smart materials that turn ordinary matter into highly prized materials;[30] we call it nanotechnology. What medieval alchemists could not have known is that to get to this desired state of affairs – turning ordinary materials into highly prized ones – they needed the help of physicists, engineers, biologists and computer scientists. This is called the convergence that leads to the phenomenon called nanosciences and technologies.[31]

Eric Drexler[32] started the debate around nanotechnologies and futuristic visions using both *engine* and *creation* in the title of his now famed book. Inadvertently or not, it points to the essence of the subject at hand, it has both mechanical and biological figments. Chemistry is not an engine, but it is involved in emergence (creation) of biological systems as such. If we are to associate creation with the growth and

[28] Ludicrous is the word of choice to convey the fact that many quantum phenomena are beyond what the human min dis willing, capable or trained to believe.

[29] Vogel, R, Pharmaceutical Economics and Public Policy, Pharmaceutical Products Press, 2006. at 5.

[30] For instance, nanotechnology research results point to the possibility of replacing rare earth elements used in electronics fabrication with nanomaterials made from more globally equally distributed chemical elements. While rare earth elements are per se not rare, their mining can be rather intensive and they are not found in all geographical regions in the way silicon, carbon, nitrogen or hydrogen are.

[31] Refer to either Schummer or Bainbridge in 16.

[32] Drexler, KE, Engines of creation: The coming era of nanotechnology, Anchor Press New York, 1987.

reproduction of living organisms, the engines of life are chemical processes.[33] Ultimately, what allows the assembly of nanoparticles, be it in natural or engineered processes, are chemical processes (better known as chemical reactions or interactions).

That some aspects of nanotechnology are essentially, but not only, a further development in chemical sciences, is perhaps too subtle an issue to merit much attention beyond that which historians and philosophers of science like to devote to it. It is exactly this subtle point of the nature of what the technology in nanotechnology is about, however, that is most relevant to the legal disciplines, in particular to patent law. That is, be it in biological processes or in nanotechnological processes, what we are dealing with are chemical processes. If Drexler used the term 'self-assemblers' this was because he lacked knowledge about the nature of chemical processes, which are always self-assembling. Thus using engineering metaphors and those of mechanics seems obvious, but at the same time, it is misleading and detracts from the fundamental nature of the science that is the basis of this technology. Moreover, biomimetics is emerging as a strong nanotechnology engineering discipline, and it has no other aim than to discover and invent processes that are developed along life's yet unravelled principles and that are presumed likely to be sustainable.[34] Biomimetics[35] in itself is not new; engineers have often borrowed nature's technical solutions and applied them to new inventions such as the design of aeroplanes following Leonardo da Vinci's example of bird's flight studies to inspire his proposed flying machines.

However this is not a debate about classification of nanotechnology – claimed as the newest field of human endeavour[36] – into a new discipline, it is an attempt at elucidating the nature of the subject matter, namely nanomaterials,[37] that we are subjecting to a specific legal regime, that of patent law. Next, for the purposes of illustration, we consider *spin* as one of the quirky manifestations of nature at the quantum scale.

2. *Intuition and Spin*

The electron – the fundamental particle involved in chemical bonding, the same electron that is the working agent in electronic devices, and the product of electrical

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[33] Life can be viewed as a shuffling of energy through chemical processes mediated by an array of molecular structures.

[34] IC Gebeshuber, P Gruber, & M Drack, 'A gaze into the crystal ball: Biomimetics in the year 2059', *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science* vol. 223, no. 12, 2009, pp. 2899-2918; B Bhushan, 'Biomimetics: lessons from nature - an overview.', *Philosophical Transactions of the Royal Society A Mathematical, Physical & Engineering Sciences* vol. 367, no. 1893, 2009, pp. 1445-1486; C Tamerler, D Khatayevich, M Gungormus, T Kacar, EE Oren, M Hnilova, & M Sarikaya, 'Molecular biomimetics: GEPI-based biological routes to technology.', *Biopolymers* vol. 94, no. 1, 2010, pp. 78-94.

[35] Biomimetics is an interdisciplinary engineering field focused on the imitation of nature, not just at the mechanical level, but also at the atomic and molecular scales.

[36] G Marchant, & D Sylvester, 'What Does the History of Technology Regulation Teach Us about Nano Oversight?', *The Journal of Law, Medicine & Ethics* vol. 37, no. 4, 2009, pp. 724-731.The claim made in the first paragraph is that "nanotechnology is the latest in a growing list of emerging technologies that includes nuclear technologies, genetics, … ."

[37] We focus on nanomaterials, the products of the technologies grouped under nanotechnology. This focus is necessary as patent law deals with products, processes or methods invented in any technology.

generators – has a physical dimension called *spin* that can have a value of either +½ or −½. A chemist may refer in the same breath to an electron spin being 'up' or 'down' and 'orbital momentum' that are assigned various discrete values thus enabling logical (mathematical) manipulation and computation. In fact, chemical bonding is – loosely speaking – governed by spin. A chemical bond is formed when two electrons with different spins are at the same energy level shared by two atoms. If the two electrons, for whatever reason, find themselves at the same energy level and with the same spin, then they will not contribute to the formation of a chemical bond by not remaining at that energy level. Together, spin and orbital momentum give the electron its angular momentum. Orbital angular momentum is of great significance in the type of bonding that the atom or molecule forms. Electron spin resonance is a technique used to study molecular species that have one unpaired electron (radicals). In the presence of a magnetic field, the unpaired electron will give a signature signal that allows inference about the presence and nature of such a molecular species.[38] Aside from the esoteric language of quantum mechanics and the various labels that it uses to abstractly handle the observable phenomena, spin is just not the kind of physical property that can easily be understood through common sense intuition. In the theory of quantum mechanics it allows for the understanding through abstraction of many atomic, molecular and material properties.

Electron spin is of special interest in areas of solid-state memory devices where current research and development efforts explore this property.[39] Beyond the implication of physical properties that elude present intuition, of which spin is but one example, there are more fundamental novelties associated with nanotechnology which are still being discovered.

The concept of spin may only make sense to physicists and chemists. It is, however, but one of the fundamental concepts that permit an understanding of nanotechnology. With the formulation of the theory of quantum mechanics, and the discovery and study of the physical effects explained by it, it became necessary to develop a language appropriate to what was observed. That this language does not make sense to legal scholars is understandable, however unfortunate. Thus the necessity to translate the abstractions of the quantum world of chemistry to distinctions that are useful in the legal regime, and in particular in patent law, becomes acute when the technologies – nanotechnologies – that dominate scientific research and technological development are governed by its laws. We offer the distinction between simple and complex machines as one that could be useful for the task of translating the abstractions of the quantum world to that of the legal regime. One fundamental aspect of the novelty in the nanotechnologies is its potential for the manufacture and creation of complex systems (engines and machines) and the extension of those techniques to biomimetics, and ultimately to synthetic biology.

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[38] Better known than electron spin resonance, is nuclear magnetic resonance, which is a technique widely used in medical imaging, but that, instead of exploiting electron spin, exploits proton spin.

[39] See for example: L Bogani, & W Wernsdorfer, 'Molecular spintronics using single-molecule magnets', *Nature Materials* vol. 7, no. 3, 2008, pp. 179-186; S Sanvito, 'Organic spintronics: Filtering spins with molecules', *Nature Materials* vol. 10, no. 7, 2011, pp. 484-485.

3. *Simple and Complex Machines*

"Quantum mechanics is to atoms and molecules what classical mechanics is to engines."[40] While the science and technology that have served the industrial development of chemicals have been using quantum mechanics as a theoretical basis, the mechanical world of steam engines and electric machines is still using classical mechanics. These two very distinct science and technology areas have been served by the same patent system; however, not surprisingly, the practice in the two areas has diverged. The patent system has treated chemicals with the same reductionist approach that it uses for steam engines and can openers. We question the validity of this approach, and ask what consequences this may have in elucidating the patentability of nanotechnology inventions.

Understanding the differences between classical and quantum mechanics can help one to understand better the divergence in patent law practice between classical machines and chemical-related inventions. The juxtaposition of the two different models of nature – classical mechanics and quantum mechanics – allows for the questioning of the rationale applied to justify the divergence in patent practice between (a) chemicals, biotechnology, and genes, and (b) classical electric, electronic, or mechanical machines. In nanotechnology, the world of mechanics (b) joins the chemical world (a), and one is left pondering where to classify it. However this is not a problem of patent classification, it is a problem with epistemic classification of a technology that challenges existing models (theories) and common sense. The preoccupation with the classification of the technology then leads to the question of what is truly created by humans, and what is created by nature itself.

A steam engine from the heyday of the industrial revolution is an engine that transforms one form of energy into another and there is no doubt that human ingenuity and creativity produced that engine. In contrast molecular motors such as myosin[41] or kinesin,[42] which perform exactly the same function of converting one form of energy into another, have evolved through natural processes and without human intervention. These are two distinct categories of engine. The first kind is called a (Cartesian) simple engine, and the second kind is a (von Neumann) complex engine.

Fuelling much of the hype on nanotechnology is Drexler's famous book *Engines of Creation*. One can argue that these 'engines of creation' imagined by Drexler are neither standard mechanical machines or simple machines, nor are they complex systems within the von Neumann model of complex machines.[43] Drexler's assemblers

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[40] See 29. Furthermore Lloyd offers the view that "all interactions between particles in the universe convey not only energy but also information." That is, particles not only collide or interact, but they also exchange information, thus compute. In brief, as the universe unfolds it is actually computing itself in what is called a dynamical evolution. "The digital revolution today is merely the latest in a long line of information-processing revolutions stretching back through the development of language, the evolution of sex, and the creation of life, to the beginning of the universe itself."

[41] Myosin comprises a family of adenosine tri-phosphate (ATP) dependent motor proteins that are responsible for muscular contraction.

[42] Kinesin proteins are also motor proteins and are powered by hydrolysis of ATP.

[43] X Guchet, & B Bensaude-Vincent, 'Nanomachine: Technological Concept or Metaphor?' in F Jotterand (ed.), *Emerging Conceptual, Ethical and Policy Issues in Bionanotechnology*, Springer, 2008, pp. 27-41.

and "Grey Goo" take a purely exploitative view of nature adopting a bottom-up approach to assembly in an indiscriminate atom-by-atom manner.[44] In the Cartesian model of a machine each part has been individually designed to perform a specific task and when all parts are assembled according to the engineer's design, it will perform in a perfectly predictable and understandable way. A classical steam engine or an egg-beater are good examples of Cartesian machines. Cartesian machines and simple engines exhibit behaviours that can be completely described. By contrast a von Neumann complex machine "cannot be deduced and does not pre-exist in the mind of its designer."[45] This complex machine, or automaton, is capable of such complicated behaviour "that it is impossible to describe it completely and unambiguously" as to its functions. [46] That is, as von Neumann posited, there is a threshold of complexity at which "the structure of an object becomes simpler than the description of its properties."[47] Thus, while one can document procedures for assembling both Cartesian and von Neumann machines, the latter's behaviour is more complex than what our representational methods can describe. Good examples of complex machines are molecules such as myosin or kinesin. Molecular structure can be completely determined by the physical methods of natural science, however, the function of such a molecule or how it performs that function are often surprising and very much the subject and object of discovery. This is in fact what we observe with nanomaterials.

III. Nanotechnology Patents

Nanotechnology patents and nanotechnology are the topic of many dedicated journals such as *Nature Nanotechnology* or *Recent Patents in Nanotechnology*. The European Patent Office (EPO) has addressed the expectation and resulting numerous applications by creating an internal working group on nanotechnology.[48] There is significant consensus that nanotechnology and other enabling technologies could help society deal with many of the challenges of this century, including those of climate change, energy, health, food and agriculture, communication, and security.[49] In

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[44] The Grey Goo model has been discredited by chemists, and abandoned by its author: for a deeper analysis of the controversy see O Bueno, 'The Drexler-Smalley Debate on Nanotechnology: Incommensurability at Work?' in J Schummer, & D Baird (eds.), *Nanotechnology challenges: implications for philosophy, ethics and society*, World Scientific Pub., 2006, pp. 29-48.

[45] See 43 at 31.

[46] Ibid.

[47] J-P Dupuy, & A Grinbaum, 'Living with Uncertainty: towards the Ongoing Normative Assessment of Nanotechnology' in J Schummer, & D Baird (eds.), World Scientific Pub., 2006, pp. 287-314.

[48] M Scheu, V Veefkind, Y Verbandt, & E Galan, 'Mapping nanotechnology patents: The EPO approach', *World Patent Information* vol. 28, 2006, pp. 204-211.

[49] The literature about nanotechnology applications is vast. Nanotechnology is a general purpose technology, thus its methods and application affect all areas of technology. See for example: TA Faunce, 'Nanotherapeutics: new challenges for safety and cost-effectiveness regulation in Australia', *Medical Journal of Australia* vol. 186, no. 4, 2007, pp. 189-191; TA Faunce, 'Global Medicine and Human Biosecurity: Private Interests, Policy Dilemmas, and the Calibration of Public Health Law', *The Journal of Law, Medicine & Ethics* vol. Winter, 2007, pp. 629-642; FAO/WHO, 'FAO/WHO Expert Meeting on the Application of Nanotechnologies in the Food and Agriculture Sectors: Potential Food Safety Implications', *FAO/WHO Expert Meeting on the*

addition, quantum dots are finding applications across a range of sectors that further demonstrate how diverse the various nanotechnologies are.[50] Accordingly nanotechnology discoveries and inventions are being claimed in all areas of science and technology in a fashion reminiscent of the gold rush.[51] Besides the actual study of concrete patent specifications or applications, it is useful to look at the level of activity reported in the various jurisdictions in both developed and transitional economies, or to study at length the data available.[52]

A. Inventions and Technologies

Nanotechnology-related inventions are numerous. At the EPO these fall into two main categories: inventions with a controlled geometric size of at least one functional component, and inventions relating to equipment and methods for analysis, measurement, processing, manipulation and fabrication below 100 nm.[53] Getting a firm grip of the number of patents in this category is difficult as it depends on the search strategies, databases, keywords, and patent classifications used, which make the numbers from different studies incomparable. In any case the various reports on the analysis of bibliographic data on nanotechnology-related patent applications and patents provide some guidance to the overall inventive activity in the area.

In 2010, the number of US patents granted, which were officially classified in the nanotechnology class[54] by the United States Patent and Trademark Office (USPTO)

Application of Nanotechnologies in the Food and Agriculture Sectors: Potential Food Safety Implications 2009, pp. 1-104; R Kalpana Sastry, HB Rashmi, & NH Rao, 'Nanotechnology for enhancing food security in India', *Food Policy* vol. 36, no. 3, 2011, pp. 391-400; LJ Frewer, W Norde, & A Fischer, 'Nanotechnology in the Agri-Food Sector: Implications for the Future', *Implications for the Future* 2011, pp. 328.

[50] CA Charitidis, A Golnas, F Chouliaras, N Arpatzanis, CA Dimitriadis, JI Lee, & C Bakolias, 'QD technology and market prospects in the sectors of space exploration, biomedicine, defense, and security', *physica status solidi (c)* vol. 5, no. 12, 2008, pp. 3872-3876; JE Riviere, 'Pharmacokinetics of nanomaterials: an overview of carbon nanotubes, fullerenes and quantum dots.', *Wiley Interdisciplinary Reviews: Nanomedicine and Nanobiotechnology* vol. 1, no. 1, 2009, pp. 26-34; K Sanderson, 'Quantum dots go large.', *Nature* vol. 459, no. 7248, 2009, pp. 760-761.

[51] Hebert, P, *Nanotechnology gold rush yields crowded, entangled patents*, 2005, retrieved 5. 08. 2010, <http://www.luxresearchinc.com/press/RELEASE_IPreport.pdf>; M Lemley, 'Patenting nanotechnology', *Stanford Law Review* vol. 58, 2005, pp. 601-630; R Bawa, SR Bawa, & SB Maebius, 'The Nanotechnology Patent 'Gold Rush'', *Journal of Intellectual Property Rights* vol. 10, 2005, pp. 426-433; J Fromer, 'A Psychology of Intellectual Property', *Northwestern University Law Review* vol. 104, no. 4, 2010, pp. 1441-1510.

[52] X Li, Y Lin, H Chen, & M Roco, 'Worldwide nanotechnology development: a comparative study of USPTO, EPO, and JPO patents (1976–2004)', *Journal of Nanoparticle Research* vol. 9, 2007, pp. 997-1002; X Li, H Chen, Y Dang, Y Lin, C Larson, & M Roco, 'A longitudinal analysis of nanotechnology literature: 1976–2004', *Journal of Nanoparticle Research* vol. 10, 2008, pp. 3-22; X Li, D Hu, Y Dang, H Chen, M Roco, & C Larson, 'Nano Mapper: an Internet knowledge mapping system for nanotechnology development', *Journal of Nanoparticle Research* vol. 11, 2009, pp. 529-552.

[53] Verbandt, Y, C Kallinger, M Scheu, & W Förster, *Nanophotonics technology watch at the European Patent Office*, 2008, retrieved 13. 03 2012, <http://link.aip.org/link/PSISDG/v6988/i1/p69880W/s1&Agg=doi>.

[54] USPTO Class 977 and a cross reference art collection; retrieved 9.11.2011 <http://www.uspto.gov/web/patents/classification/uspc977/sched977.htm>. Besides the US classification, the EPO, JPO and World Intellectual Property Organization (WIPO)

was 5,962.[55] According to a patent publication analysis for USPTO, EPO, and Japan Patent Office (JPO) data from 2005–2007, Switzerland ranks 11th on a list headed by the US, Japan, Germany, and China.[56] For example, more than 350 nanotechnology-related inventions[57] assigned to 140 Swiss entities were found up to 2010.[58] Another study finds that China has an above-average growth rate in nanotechnology patents, and Germany a below-average rate.[59]

A breakdown of the State Intellectual Property Office of the People's Republic of China (SIPO) patent applications by country or region from 1991 to 2006 puts China at the top of the list with 11,065, followed by the US with 1,072, Japan with 623, Republic of Korea with 409, Taiwan with 305, and by Germany, the Netherlands, and France, all with more than 100 applications pending.[60] It is not surprising that China heads this list, accounting for approximately 77% of all nanotechnology patent applications in the SIPO database. In Taiwan, courts issued specific guidelines which call for the close scrutiny of invention step, utility and enablement to provide assistance with nano-based Chinese herbal medicine (CHM) patents.[61] In China the particular case of nano-based CHM patents has generated the concern that there is an irrational exuberance in patenting these applications which "will surely act as a barrier to innovation and invention in the emerging biopharmaceutical industry and nano based CHM market."[62]

(International Patent Classification, IPC) have also established criteria on patent classification for nanotechnology-related inventions. The EPO's nanotechnology European Classification System (ECLA) sub-class is B82Y and it comprises nine main groups; retrieved 9.11.2011 <http://www.epo.org/news-issues/issues/classification/nanotechnology.html>. See also Watal, A, & TA Faunce, *Patenting Nanotechnology: Exploring the Challenges*, retrieved 28. 6. 2011, <http://www.wipo.int/wipo_magazine/en/2011/02/article_0009.html>.

[55] S Maebius, & D Jamison, 'Nanotechnology Law & Business Turns Seven', *Nanotechnology Law & Business* vol. 7, 2010, pp. 1.

[56] See Chen, H, & M Roco, Mapping Nanotechnology Innovations and Knowledge: Global and Longitudinal Patent and Literature Analysis, Springer, 2008; A McGibbon, C Soltmann, & R Boutellier, 'Assessing the Swiss Nanotechnology Landscape', *Nanotechnology Law and Business* no. 7, 2010, pp. 366-379. Appendix, Table A1 at 299 for the complete ranking.

[57] Inventions is used here instead of patents because in this study what was counted were the number of patent families, not the number of patents. Depending on how significant and what market it is destined for, an invention may have a large number of patents in its patent family. Each member of a patent family counts as a single patent, however the ensemble counts as just one invention.

[58] See McGibbon *et. al.* in 56.

[59] Preschitschek, N, & D Bresser, *Nanotechnology patenting in China and Germany – a comparison of patent landscapes by bibliographic analyses*, 2010, <http://www.businesschemistry.org/article/?article=109>.

[60] R Parker, C Ridge, C Cao, & R Appelbaum, 'China's Nanotechnology Patent Landscape: an Analysis of Invention Patents Filed with the State Intellectual Property Office', *Nanotechnology Law and Business* vol. 6, 2009, pp. 524-539.; East Asian patent application filers (China, Japan, and the Republic of Korea) using the Patent Cooperation Treaty (PCT) system now outnumber those in North America and Western Europe as of 2010. Source: WIPO statistics, downloadable at www.wipo.int/ipstats/en/statistics/pct/ (26.5.2011).

[61] JI-H Hsiao, 'Nanotechnology Meets Chinese Herbal Medicine: an Introduction to the Patenting of Nano-Based Chinese Herbal Medicine in Taiwan', *Nanotechnology Law Business* vol. 7, 2011, pp. 80-96.

[62] T-P Dong, & C-H Sung, 'Exuberance or Bubble? Study of Nano-Based Herbal Medicine Patents in the PR China', *Journal of Intellectual Property Rights* vol. 16, 2011, pp. 225-234.

For Russia, patent analysis indicates that between 1997 and 2005 nanotechnology patent activity increased considerably, and that there is a specialization in nano-optics and nano-mechanics, whereas nano-biotechnology shows no such specialization.[63] This gives an indication of both the diversity of the technological fields and the fact that there are different regional specializations. A brief sampling of the nanotechnology-related patents on record follows, all of which involve some aspect of the chemistry of carbon.

1. *Patents Involving Carbon Allotropes*

Carbon allotropes[64] are all the rage in nanomaterials, and have been the subject of much of the pioneering research that led to the development of the nanotechnology.[65]

a) **Buckyballs**

The case of buckyballs[66] is illustrative of a nanomaterial that existed in nature but was only discovered in nature after its laboratory discovery.[67] The patent applications for fullerenes – the broader class of carbon molecules to which buckyballs belong – have often been interpreted to mean ownership of the molecule, and that by interpolation, techniques for the precise manipulation of atoms open up a whole new terrain for private ownership, such as is the case of genes which are claimed to be "controlled by patents."[68] As it was for buckyballs, so it has been for many other developments in science in technology where the discovery of a new aspect of nature, or a new law of nature, leads to considerable research activity in the pursuit of what are thought to be potential beneficial applications that can be successfully commercialized. Patents applications involving fullerenes have been filed and granted; however, after a great deal of initial excitement about their potential for revolutionary applications from rocket fuels to drug carriers, the attention and patent filing activity have turned to other nanomaterials.[69] In Europe between 300 and 400 businesses, research institutions, universities and independent inventors hold patents or applications

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[63] T Reiss, & A Thielmann, 'Nanotechnology Research in Russia - an Analysis of Scientific Publications and Patent Applications', *Nanotechnology Law & Business* vol. 7, 2011, pp. 387-404.

[64] Allotropy is the variation of physical properties without change of substance to which certain elementary bodies are liable. First noticed by Berzelius in the case of charcoal and diamond. (allotropy, n. Second edition, 1989; online version March 2011. <http://www.oed.com:80/Entry/5444>; accessed 31 May 2011. Earlier version first published in *New English Dictionary*, 1884.)

[65] J Luis Delgado, M Angeles Herranz, & N Martin, 'The nano-forms of carbon', *Journal of Materials Chemistry* vol. 18, no. 13, 2008, pp. 1417-1426.

[66] A buckyball is a carbon cage where the vertices are occupied by a carbon atom such that in its geometry it resembles a geodesic dome as invented by Buckminster Fuller. Buckminsterfullerene is a 60 carbon molecule having a van der Waals radius of about 1 nanometre (nm).

[67] H Kroto, 'New insights in to the mechanisms of fullerene and nanotube formation', *IEEE 18th International Vacuum Nanoelectronics Conference* 2005, pp. 1-37.

[68] Arnall, AH, *Future technologies, today's choices: nanotechnology, artificial intelligence and robotics; a technical, political and institutional map of emerging technologies*, 2003, retrieved 12. 04. 2010, <www.greenpeace.org.uk>. at 10.

[69] R Michalitsch, C Kallinger, Y Verbrandt, V Veefkind, & SR Huebner, 'The Fullerene Patent Landscape in Europe', *Nanotechnology Law &Technology* vol. 5, 2008, pp. 85. at 86.

relating to fullerenes, however only approximately 10% of those hold more than one; the US and Japan have had a higher patenting activity for fullerenes.[70]

So far, fullerenes have found hardly any practical applications. Carbon nanotubes have done better in finding practical applications, these are however costly to produce and difficult to control,[71] and it is predicted that these will be replaced by graphene as the material of choice in nano-enabled electronic devices.[72]

b) Graphene and Carbon Nanotubes

A carbon nanotube (CNT) is a rolled up sheet of graphene[73] that can be produced in a variety of ways, however this is a very active area of research.[74] In 2010, graphene which is being considered for the same types of applications as CNTs, was the subject of more than 3,000 research papers and more than 400 patent applications.[75] Both materials are still quite challenging in their preparation, which in part explains the expansive patenting activity involving these two nanomaterials.[76]

The first US patent application with the expression "carbon nanotube" appearing in the claims was filed in 1993.[77] Since the year 2000 patent applications for inventions involving CNTs have undergone what is qualified as an explosive growth. The leading applicants are Samsung, Hon Hai, IBM, Intel, DuPont, Eastman Kodak, Fuji Xerox, NASA, Rice University, Nantero, Honda, Mitsubishi, Hyperion Catalysis International, and Applied Nanotech Holdings.[78] The patenting of CNT has created what some authors call a patent thicket. Here the concern is that many of the applications or patents are wide in claim scope, and that their validity may questioned on other grounds. In particular the application of legal uncertainties in patent law doctrines such as patentable subject matter, novelty, obviousness, and enablement are thought to challenge CNT patent claims.[79]

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[70] Ibid.

[71] R van Noorden, 'Chemistry: The trials of new carbon.', *Nature* vol. 469(7328), no. 7328, 2011, pp. 14-16.

[72] AS Baluch, B Wilson, & JC Miller, 'Patenting Graphene: Opportunities and Challenges', *Nanotechnology Law & Business* vol. 5, 2008, pp. 289-299.

[73] Graphene is a single atom layer (atomically thin mesh) of carbon atoms arranged in a honeycomb (hexagonal) pattern. Because of the high strength of the carbon–carbon bonds in this allotrope of carbon, it has an exceptionally high strength-to-weight ratio; see 71.

[74] RM Frazier, DT Daly, RP Swatloski, KW Hathcock, & CR South, 'Recent Progress in Graphene-Related Nanotechnologies', *Recent Patents on Nanotechnology* vol. 3, no. 3, 2009, pp. 164-176.

[75] See 71.

[76] See 74.

[77] U.S. Patent No. 5,346,683, filed Mar. 26, 1993, granted Sept. 13, 1994, inventors Green et al.

[78] MH Heines, 'Carbon Nanotubes: Tracing the Growth of a Young Technology Through Patents', *Nanotechnology Law and Business* vol. 7, 2010, pp. 21-37.

[79] See J Miller, & D Harris, 'The Carbon Nanotube Patent Landscape', *Nanotechnology Law & Business* vol. 3, 2006, pp. 427-454.; and for a detailed discussion of CNT patent thickets see D Harris, 'Carbon Nanotube Patent Thickets' in F Allhoff, & P Lin (eds.), *Nanotechnology and Society: Current and Emerging Ethical Issues*, Springer Netherlands, Dordrecht, 2009, pp. 163-184.

The patenting of graphene has highlighted more of the already known problems with the patent system. Patent attorneys have argued the relevance of the obviousness doctrine post *KSR International Co v Teleflex Inc*[80] where the Supreme Court rejected a rigid application of the so-called *teaching, suggestion, or motivation*[81] test and invalidating a patent on the grounds of obviousness.[82] Some argue that his ruling has in effect made it easier for US courts to rule an invention as obvious, thus not patentable, others interpret it as noticeably cautious and equivocal.[83] The concern that arises in the particular case of graphene from the side of the patent attorney is that now CNT prior art can be held against graphene inventions and render them obvious.[84] However for the purposes of this paper, obviousness considerations are not the focus of interest as these are to be taken into account once the presumed invention has been found to meet the criteria for being an invention as such, and ruled out as a discovery or a law of nature. We are concerned here with the issue of determining if the presumed invention is actually a discovery and how to effect that determination.

2. *Self Assembling Peptides in Electronic Materials*

As an example of how the patent information is being used to generate a narrative of concern, let us look at one specific example that is listed by the ETC Group in its latest report:[85] the peptide claimed in US Patent 7,449,445where claim 1 reads:

> A conductive peptide nanofiber which comprises a nanofiber formed through a manner of self assembly of a peptide that has a nanofiber-forming ability and consist of a the amino acid sequence SEQ ID NO: 2 and a conductive substance added thereto, wherein, said conductive substance is being added to an amino group of said peptide.[86]

This claim is for the amino acid sequence specified in the specification in the presence of a conductive substance, it does not claim self assembly as such, but makes use of molecular self assembly to create what is termed a nanofibre that can then be used for specific technological purposes. It is noteworthy that self assembly is better known among biological molecules than it is for those used for electronic devices.[87] In fact, "it is one of the major chemist's motivation to see that biology

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[80] KSR International Co. v Teleflex Inc, 127 S. Ct 1727 (2007), decided April 30, 2007.

[81] The *teaching, suggestion, or motivation* (TSM) test serves to prevent against hindsight. "[A] patent claim is only proved obvious if 'some motivation or suggestion to combine the prior art teachings' can be found in the prior art, the nature of the problem, or the knowledge of a person having ordinary skill in the art." in 80 at 1735.

[82] See 72.

[83] MJ Dowd, KC Bass III, & RG Sterne, 'KSR International Co. v. Teleflex Inc.: Another Small Issue for Nanotechnology', *Nanotechnology Law & Business* vol. 4, 2007, pp. 293-311.

[84] For a complete analysis of the issue of obviousness in the case of graphene in the US see: Baluch, Wilson, & Miller, *Patenting Graphene: Opportunities and Challenges.*

[85] Available at: http://www.etcgroup.org/documents/Com8788SpecialPNanoMar-Jun05ENG.pdf (26.5.2011)

[86] US Patent 7,449,445, Conductive Peptide Nanofiber and Method of Manufacture of the Same, filed: Oct 19. 2005, granted Nov 11, 2008.

[87] H Choi, & CCM Mody, 'The Long History of Molecular Electronics: Microelectronics Origins of Nanotechnology', *Social Studies Of Science* vol. 39, no. 1, 2009, pp. 11-50; CA Hauser, 'Nanotechnology: Peptides as biological semiconductors', *Nature* vol. 468, 2010, pp. 516-517.

successfully made highly complex properties on a molecular basis."[88] Furthermore synthetic biology – a further advance of science that shares with nanotechnology the close association of cognitive, technological and commercial aspects – is a project on the re-engineering of life and the utilization of life's diverse solutions to process information, materials and energy.[89] Molecular self assembly is, presumably unconsciously, often equated with living organisms. As a consequence this presumed mental equation often raises concerns among those with insufficiently detailed knowledge of the specifics of patent claim drafting. Thus the examination of such concerns as expressed in the vast literature of nanotechnology is of value in elucidating the relationship between the evolving frontier of science and the efforts of regulation. However before going into the technical details, one must not forget that all chemistry includes aspects of self-assembly some of which lead to macromolecules, others to crystal formation, and of course, there are also instances when elements or molecules will not chemically bond. That is, the use of self assembling molecules in an invention cannot possibly be construed as capturing a law of nature, or a discovery of such a natural law in the patent's claim.

3. *Mechanosynthesis of Diamond*

Hailed as one of the first diamond mechanosynthesis patents, US Patent 7,687,146 was granted on 30 March 2010; it has been classified as a nanotechnology invention. It claims a "capped tooltip molecule having a tip end and a nucleation-site handle end distal to the tip end, wherein the capped tooltip molecules comprises: one or more adamantane … " The first independent claim goes on to specify a list of hundreds of chemical fragments all of which can be used with the capped carbon. It is hard to make a call on such a patent, and more difficult is the fact that given the breadth of choice of chemical entities in the claims, the wide scope pretentions of the specifications, and the scientific nature of the specification narrative, it may invite a challenge on several grounds (obviousness, scope, enablement). It could also be that this patent is an interesting exercise, but that it may never be the subject of either commercial-scale applicability, or a patent dispute and its existence would have served more of a public relations function than that of an intellectual or technical advance. The device in US Patent 7,687,146 is however one for molecular (diamond) fabrication, and in that respect is a Cartesian device; albeit complicated, it is not a complex system.

B. The Size Arguments

When nanotechnology is mentioned, allusion is often made to size and the significance of size. We have so far refrained from these arguments because, from a chemical or scientific perspective, the size arguments are not relevant as these are representatives of a Cartesian model which does not apply at the quantum level. That is, from a chemical perspective, the size argument vanishes. However the size arguments must be heard for good reasons especially concerning occupational health issues affecting those working within the industry and for general regulatory purposes. In these non-patent related areas, size arguments are relevant because nano-sized

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[88] B Bensaude-Vincent, 'Two Cultures of Nanotechnology' in J Schummer, & D Baird (eds.), *Nanotechnology challenges: implications for philosophy, ethics and society*, World Scientific Pub., 2006, pp. 7-28. at 17.

[89] Ibid.

particles can and will traverse the blood–brain barrier and their short and long term health effects must be considered in the regulatory effort.[90] However the technical matter of patents raises other legal concerns and regulatory purposes, and size considerations have not yet provided for substantial case law. Nonetheless the EPO has heard and ruled on a case where size arguments were invoked. In *BASF/Orica Australia*[91] the EPO rejected obviousness arguments based on synthesis temperature for polymer particles of 100 nm or less, where it argued that particle size was just a subordinate element. Size issues may be relevant in nanotechnology patents when they are included in the claims, as in *Nanosized catalyst/General Electric* below. In this case the deciding factor was the unity of the invention, not the size itself, even though the argument involved the method for size determination. In fact, the EC recommendation on the definition of nanomaterials alludes to the need to develop harmonized size measurement methods.

C. Patent Disputes Involving Nanotechnology

The cases involving patent law and nanotechnology thus far can be qualified as the usual "legal skirmishes" and outside the scope of the invention–discovery dichotomy.[92] At this time, there is no case law that can be used to cement the broad concerns about nano-patents invoked in the literature and cited in the introduction to this paper. So far the disputes involving nanotechnology patents do not stand out as stemming from nano-specific issues, but include those associated with patent thickets. For example, Nanosys, a 2001 US start-up that amassed a significant patent portfolio in a rather short time claimed infringement of their quantum dot patents by Nanoco Technologies (UK) and settled in 2009 when Nanoco agreed to terminate its current US business activities in quantum dots.[93] Whether or not this case is an example of a patent thicket or of a set of "strong foundational patents of broad scope that have been shown to stifle innovation"[94] is open to further analysis. Patent thickets in nanotechnology have received some attention.[95] Several strategies have been considered to address this problem, among them patent pooling using standards or

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[90] According to the EC recommendation referenced in 21, there is no unequivocal scientific basis to suggest a specific value for the size distribution of a nanomaterial as "a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm – 100 nm." However the EC recommendation is subject to revision by December 2014.

[91] *BASF/ Orica Australia* Boards of Appeal of the EPO, T-0547/99 (8 January 2002).

[92] See also McLennan, & Rimmer, *Cosmo, Cosmolino: patent law and nanotechnology.*at 269-70

[93] Nanosys Inc. v Nanoco Technologies Ltd., case number 09-cv-00259, in the U.S : District Court for the Western District of Wisconsin. See also Ibid.

[94] A Makker, 'The Nanotechnology Patent Thicket and the Path to Commercialization', *Southern California Law Review* vol. 84, 2011, pp. 1163-1403.

[95] R Bawa, 'Will the nanomedicine "patent land grab" thwart commercialization?', *Nanomedicine: Nanotechnology, Biology and Medicine* vol. 1, 2005, pp. 346-350; G Clarkson, & D DeKorte, 'The problem of patent thickets in convergent technologies', *Annals of the New York Academy of Sciences* vol. 1093, 2006, pp. 180-200; A Lee, 'Examining the Viability of Patent Pools for the Growing Nanotechnology Patent Thicket', *Nanotechnology Law & Business* vol. 3, no. 3, 2006, pp. 317-327; Miller, & Harris, *The Carbon Nanotube Patent Landscape*; J D'Silva, 'Pools, Thickets and Open Source Nanotechnology', *European Intellectual Property Review* vol. 31, no. 6, 2009, pp. 300-306.

reference models that provide a mechanism for clearing the nano-thickets and bringing nanotechnology-based products to the market.[96] Another suggestion, in view of the growing number of nano patent thickets, and arguing on the basis of the information-physical-biological sciences convergence, is that of moving towards an open source model where the formation of patent pools is impractical.[97] In an overview of questions of law and regulation concerning the patentability of inventions in the field of nanotechnology, the idea is advanced that "a certain risk of over-patenting can theoretically be deduced."[98] However, patent thickets are a systemic problem, and not within the scope of the invention discovery distinction.

Besides the already mentioned *BASF/Orica Australia* in 2002 heard at the EPO, what is arguably the first nanotech patent case in the US Federal Circuit – relating to an invention of alumina nanoparticles that are useful for chemical-mechanical polishing of ultra-smooth surfaces – was adjudicated on procedural grounds in 2005.[99] Of significance in *re Kumar* is that the court treated the nanotechnology patent appeal no differently than patent appeals involving other technologies and that the court provides nanotech inventors with guidance for overcoming obviousness.[100] However *re Kumar* while of interest in matters of obviousness, has nothing to offer that illuminates the concerns over the ownership of nature in terms of the invention–discovery dichotomy, as this was not being challenged.

Worth highlighting despite not addressing invention–discovery, is a patent infringement case of the nano-pharmaceutical reformulation of a breast cancer treatment. Although it does not deal with issues of patentability or patentable subject matter, it is of interest to give a flavour of the nature of the arguments used thus far when nanopatents are challenged. In *Elan Pharma International Ltd v Abraxis BioScience Inc Ltd* (06-438, US District Court, District of Delaware (Wilmington), 13 June 2008) a jury delivered a US$ 55.2 million verdict to the plaintiff. The pharmaceutical concerned in this patent infringement dispute is paclitaxel marketed as *Taxol* by the plaintiff Elan Pharmaceutical International (Elan) which filed the complaint in July 2006 alleging that the cancer treatment *Abraxane*, manufactured by Abraxis Biosciences (Abraxis) infringed two of Elan's patents.[101] Elan's two patents claim a nanoparticle formulation aimed at enhancing the delivery of poorly water-soluble paclitaxel (active ingredient) for the treatment of metastatic breast cancer.[102] *Abraxane* delivers the active ingredient in an efficient way while minimizing side effects using an albumin encapsulation. The patent claims in this case do involve a

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[96] See Clarkson & DeKorte in 95.

[97] See D'Silva in 95.

[98] M Schellekens, 'Patenting nanotechnology in Europe: Making a good start? An analysis of issues in law and regulation', *The Journal of World Intellectual Property* vol. 13, no. 1, 2010, pp. 47-79.

[99] In *re Kumar*, 418 F. 3d 1361 - Court of Appeals, Federal Circuit 2005; vacated and remanded the decision of the Board of Patent Appeals and Interferences of the [U.S] Patent and Trademark Office.

[100] AS Baluch, L Radomsky, & SB Maebius, 'In re Kumar: The First Nanotech Patent Case in the Federal Circuit', *Nanotechnology Law & Business* vol. 2, no. 4, 2005, pp. 342-346.

[101] *Elan Pharma. Int'l, Ltd. v. Abraxis Biosci., Inc.*, No. 06-438 (D. Del. filed July 19, 2006).

[102] WF Prendergast, & HN Schafer, 'Nanocrystalline Pharmaceutical Patent Litigation: the First Case', *Nanotechnology Law & Business* vol. 5, 2008, pp. 158-161.

nanomaterial and a pharmaceutical active ingredient; however the basis for the court's decision was not on the nano-properties of the material. It rests on the fact that the alleged infringement involves the pharmaceutical active ingredient paclitaxel's crystallinity (as opposed to an amorphous state). Thus while nanospecific elements were invoked, these were not decisive in the alleged infringement.

In *Nanosized catalyst/GENERAL ELECTRIC*[103] the EPO Technical Board of Appeal decided to dismiss the appeal of the examining division's decision that the claims in application no.01985985.9 lacked unity. The board concluded that there is no reason to assume that there is a most common method of determining the average particle size in the direct synthesis of organohalosilanes, and that the methods available differ widely in the estimates produced. That is, while the claim specifies 'average particle size of 0.1 to 600 nanometres' the appellant refers to a method of preparation, but leaves the size determination unspecified, as referring only to "methods for determining the average particle size yielding values for the same particle distribution which generally differ, under particular conditions by one or two orders of magnitude."[104] This case was decided on the basis of European Patent Convention (EPC) Article 84.[105] There were no issues of patentability or discovery, rather the case points to problems in determining particle size. Depending on the method chosen, either based on volume, mass or area, the estimated particle size (expressed in nanometres) will vary by orders of magnitude. That the methodology would yield different estimates is neither surprising, nor arbitrary. The results are reproducible for each method. In addition, because nanotechnology is an emerging technology, it is also not surprising that there is no generally acceptable single method for particle size determination.

IV. Chemistry Really: Nanomaterials and Molecules

A. *Ontological Views of Chemicals*

Limiting the analysis to the reduction of nanomaterials, self-assembling peptides, genes, or biological active chemicals, to chemicals ignores more subtle ontological arguments which are significant in dealing with patenting issues. The so-called convergence in the nanotechnologies, synthetic biology, and smart materials engineering also necessitates a broadening of the discourse. That is, a Cartesian approach to chemical entities is too limiting as it ignores the complex nature of materials in general and nanotechnology-produced objects and aggregates in particular.[106] We note that there is a difference if we consider a molecule in isolation or if we consider an aggregate of molecules.[107] If we were to observe the carbon atom

[103] Board of Appeal of the EPO: T 1819/07 (15. 3. 2011).

[104] Ibid. at 3.2; An order of magnitude refers to a factor of ten, and two orders of magnitude to a factor of one hundred.

[105] European Patent Convention, 2007;The claims shall define the matter for which protection is sought. They shall be clear and concise and be supported by the description.

[106] See 47.

[107] The argument used by the majority opinion written by Judge Laurie in *Myriad* (29 July 2011) invokes the breaking of covalent chemical bonds, and is not an equivalent argument to the present one, albeit related. In fact, we suspect that this particular issue needs much more careful analysis than it has received thus far.

in isolation and study it in all its details subject to the available tools, we would still not know anything about diamonds or graphite that are aggregate states of that particular atom.[108] In the case of carbon, the duplicity is multiplied because of the many kinds of chemical bonds that it forms.[109] Thus, there is a difference if we consider a chemical entity (atom, molecule) in isolation, or if we consider it (or use it) in an aggregated state. An isolated atom and a crystal of the same atom belong to different functional categories. Nanoparticles of the same material fall between these two extreme phases of matter. So far, the patent regime has ignored the fundamental law of nature that is reflected in the uncontested observation that isolated and aggregated atoms or molecules exhibit naturally occurring properties which are very different.[110] The consequence of ignoring this fact has led, for example, to equating a gene with a chemical compound and this paved the way to the gene's patenting.[111] This shunting of the logic of materials in favour of what could be accommodated by existing (patent) regulations does pose technical and legal problems as evidenced in the cases discussed above.

While strictly speaking both genes and ordinary chemicals are made of the same building blocks, that is, atoms, genes, unlike most conventional chemicals, operate at different functional levels. At the molecular level, and in isolation, genes or proteins can be categorized as chemicals. At the biological level genes code for one or more proteins, and at the whole organism level genes play roles related to the proteins they code for. That is, a gene in isolation is a sequence of molecules forming a chain of DNA. When part of a system, be it a cell, an organism, or a synthetic chemical medium, these same genes assume different functions as they interact with their immediate chemical or cellular environment (chemical environment, chemical context). As the scientific understanding of genes has progressed, the differentiation of the different levels of operation of these chemicals has emerged, and it allows for the questioning of the logic used to extend patentability to genes. As a result, we advance the notion that the "legal reduction of the gene to a chemical compound can no longer be supported in the context of the current practices of the scientific community."[112] Why is that? Because, as extensively discussed by Calvert and Joly, genes are very complex, there are diverse understandings of what the gene is, and in addition genes are essential facilities as in the sense of economics and antitrust law.[113]

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[108] Analogous arguments can be constructed when the unit of aggregation is an atom instead of a molecule.

[109] The chemistry of carbon is a very extensive discipline on its own, usually designated as 'organic chemistry' and that serves as a basis for the study of biological molecules or biochemistry. Biochemistry studies the functions of molecules as they are found in living organisms (plants and animals). Biotechnology involves the manipulation, transformation and exploitation of biological molecules for industrial processes.

[110] It is not just the patent regime that has ignored this universal fact. Chemical regulation is also plagued by the same fault whenever a material has several allotropic phases with dramatic differences in their properties. That is, carbon is not just carbon. Carbon is graphite, diamonds, carbon nanotubes, buckminsterfullerenes, to name but a few allotropes of carbon.

[111] J Calvert, & P-B Joly, 'How did the gene become a chemical compound? The ontology of the gene and the patenting of DNA', *Social Science Information* vol. 50, no. 2, 2011, pp. 157-177.

[112] Ibid. at 168.

[113] Ibid. at 168 citing Henry, Tommmeter and Tubiana. Facilities are here to be understood as regulatory in a generic sense. This points to a limitation in the language in use. Genes have

What can be said for genes can also be extended to complex molecules and materials produced by the technologies enabled by mimetics and biomimetics. That is, the complexity which characterizes genes, proteins, or nanomaterials is the kind of complexity that a von Neumann complex machine possesses. The structures of genes, proteins, or nanomaterials can be described, but their function cannot be unambiguously described as in the case of a Cartesian machine such as a simple steam engine. At this point we are curious as to how chemical invention has been treated in patent law in the past, and pose the question of what the lessons from that history are.

B. Highlights of the History of Chemical Invention

Throughout the history of the patent system the patentability of chemical inventions has been a subject of much debate and many changes in policy.[114] Time and space contexts locate the patentability discipline as to the determination of what is eligible as patentable subject matter. This historical and regional contextual perspective helps in understanding the interplay between the economic, political, technological, industrial and scientific discourses, all of which feed into the patent regime. The question of what is fabricated and what is natural is not a new one; it preceded biotechnology by many years, if not centuries. Thus it is no surprise to find early arguments that a "novel true chemical compound" as such, is not entitled to patent protection. That is, chemical compounds, as such, cannot be inventions because a true invention is specifically a human affair.[115] Thus the question is how chemical compounds ever came to be included as eligible patentable subject matter. The answer to this question is very different depending on the jurisdiction, and is often linked to the state of development of the national chemical industry.

In part, we owe these developments of chemical invention in patent law to German chemists dexterity's long history that brought the first synthetic dyes to the market. Largely without colonies from which to source raw materials, and wanting to reduce its trade deficit, Germany relied on coal tar as the raw material to effect substitutions through chemical transformations.[116] The chemical industry was dominated by Germany as modern patent laws were being enacted in the late 1800s and early 1900s. British industry pressed for the abolition of patent protection for chemicals in the hope of being able to imitate German dyestuffs appearing on the British market so long as they could find an alternative process for their preparation. British patent lawmakers gave in and patent law was changed in 1919.[117]

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regulatory functions that are mediated (communicated) through chemicals acting on chemicals. Gene regulation is the result of short, medium and long range chemical interactions that may also be described alternatively with physical or physiological concepts and language.

[114] For an historical perspective of the international harmonization of the patent system see: Palombi, L. 2009. Gene cartels: biotech patents in the age of free trade. Edward Elgar.

[115] CE Ruby, 'Patents for Acts of Nature', *Science, New Series* vol. 89, no. 2313, 1939, pp. 387-389; CE Ruby, 'Patents for acts of nature', *Journal of Chemical Education* vol. 16, no. 10, 1939, pp. 498.

[116] Leslie, E, Synthetic worlds, Reaktion Books, 2005.

[117] Grubb, PW, & PR Thomsen, Patents for Chemicals, Pharmaceuticals and Biotechnology: Fundamentals of Global Law, Practice and Strategy, Oxford University Press, USA, 2010. at 16-26.

Germany had passed its first unitary patent law in 1877 ahead of the signing of the Paris Convention for the Protection of Industrial Property (Paris Convention) in 1883. This initial German patent law reflected the national chemical industry campaign against including patent protection for chemical substances.[118] The rationale offered in 1877 for the exclusion of chemicals as such was that there are several processes using different starting materials that permit the synthesis of a chemical compound, and that to prevent these (through an absolute product claim for the chemical) would hinder the later invention of improved processes that would better serve the interests of the public and inventor.[119] This logic got lost along the way, and now absolute chemical product protection (independent of process) is possible within some jurisdictions although this has been late in coming even in industrialized nations such as Germany, Japan, the Netherlands, and Switzerland (1968-1978).[120] The early distinction between product and process and their respective eligibility as patentable subject matter in the context of chemical invention must be noted and emphasized as it suggests viable options for getting out of the quandary when seeking patent protection for convergence chemical inventions that are the products of a combination of biotechnology, nanotechnology, and bio nanotechnology.

Switzerland did not have a patent law until 1888, that is, five years after the Paris Convention was signed, and was a 'patent piracy' country where the products of the German chemical industry were imitated. The historical record shows that the founder of Geigy AG (later incorporated into Ciba-Geigy, then Novartis) denounced patents as a paradise for parasites.[121] Until 1888 Swiss products could be imported and sold in Germany because up to that time German industry had refused to accept product protection in its patent law while chemical processes were patentable. It was only in 1888 after the German BASF successfully sued the Swiss Geigy for infringement for selling in Germany a dye produced in Switzerland by a BASF-patent-protected process that the codification of the indirect product protection was included in

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[118] The German *Patentgesetz* of 25 May 1877 defines patentable subject matter and exclusions in §1 as follows: *"Patente werden ertheilt für neue Erfindungen, welche eine gewerbliche Verwerthung gestatten. Ausgenommen sind: 1. Erfindungen, deren Verwerthung den Gesetzen oder guten Sitten zuwiderlaufen würde; 2. Erfindungen von Nahrungs-, Genuss- und Arzneimitteln, sowie Stoffen, welche auf chemischem Wege hergestellt werden, soweit die Erfindungen nicht ein bestimmtes Verfahren zur Herstellung der Gegenstände betreffen*." (Source: *Das Patentgesetz für das Deutsche Reich. Erleutert von Dr. Otto Dambach*, Verlag von Th. Chr. Fr. Enslin, Berlin, 1877 at [1].); In English: Invention patents are granted for inventions which are of commercial utility except for: 1. Inventions which would be against the law or against good mores; 2. Inventions for food, luxury foodstuffs, medicaments, and other substances produced by chemical means, as long as the invention does not concern a specific fabrication process. (translation by the authors). Note that Article 1(3) PC is specific in defining industrial property in that the treaty "shall apply not only to industry and commerce proper, but likewise to agricultural and extractive industries and to all manufactured or natural products, for example, wines grain, tobacco leaf, fruit, cattle, minerals, mineral waters, beer, flowers, and flour" and in Article 1(4) further sets that "patents shall include various kinds of industrial patents recognized by the laws of the countries of the Union, such as patents of importation, patents of improvement, patents and certificates of addition, etc." Thus the German 1877 exclusion of substances produced by chemical means, albeit prior to the PC, is not inconsistent with it.

[119] See: Zimmerman, PA, Patentwesen in der Chemie: Ursprunge Anfänge Entwicklung, Badische Anilin- & Sodafabrik AG, Ludwigshafen am Rhein, 1965. at 36.

[120] See 117 at 77.

[121] Ibid. at 25.

German patent law in 1891. This reflects the fact that initially (1877) the sale of the product of a patented process was thought not to constitute infringement. However the Swiss patent law as enacted in 1888 excluded both substances and processes from protection as it required a 'working model' that demonstrated the invention. Product protection came in much later, in 1978. However, processes had already been protected since the 1907 enactment. The US Patent Act of 1790 established a very strict examination procedure, and it granted its first patent for a chemical invention – not a chemical compound – relating to the manufacture of pearl ash (potassium carbonate).[122]

C. Divergence of Technology and Patent Law

Science and technology advancements and revisions to patent law have moved along different trajectories. At least from a science and technology point of view the developments have not been congruent. That is, while science and technology have moved ahead by leaps and bounds, patent law has neither conserved its original design, nor has it kept pace with the developments in the basic arts feeding into the industries and publics that it serves. The subsequent patent law revisions have ignored any serious attempts at bringing its substance in line with the emerging technologies of the twentieth and twenty-first centuries such as digital technology, biotechnology, nanotechnology or synthetic biology. Instead, incongruent divergence between patent law and the technologies that it aims to encourage and harbour has proceeded uncorrected. These days patent law in most jurisdictions attends to a myriad of anti-competitive and special interests and ignores most of the more up to date and fundamental aspects of intellectual property. The recital in Article 7 TRIPS is clear that "[t]he protection and enforcement of intellectual property rights should contribute to the promotion of technological innovation and to the transfer and dissemination of technology, to the mutual advantage of producers and users of technological knowledge and in a manner conducive to social and economic welfare, and to a balance of rights and obligations."[123]

What is also clear is that at its inception, the patent system was not intended to deal with chemical invention (complex engines); rather it was designed to deal with mechanical inventions at a macroscopic scale, the so-called Cartesian machines (simple engines). When you place several pieces of wood together, they do not, according to the laws of nature assemble themselves into a chair, however, when the components necessary to synthesize acetyl salicylic acid are placed together, they can not help but react to form the chemical compound. Thus these components do assemble spontaneously (self-assembly) and under the direct influence of the laws of nature. Human ingenuity plays a role in chemical invention when it comes to applying knowledge about the conditions most favourable for the chemical reaction.

Quantum mechanics had not yet even been conceived and the chemical industry was at best embryonic and just emerging from the shadows of alchemy and sorcery when the first patent laws were being enacted. In allowing chemical processes as patentable subject matter, the patent system adjusted to the fruits of the industrial revolution without consideration as to the differences between Cartesian machines and von Neumann complex machines.

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[122] Ibid. at 20.

[123] TRIPS Article 7.

Obfuscating all earlier reason are the interpretation and arguments that patent practitioners in the pharmaceutical industries have presented to have things their way. The most frequently invoked argument for the patent protection of active pharmaceutical ingredients (chemicals) are those of investment protection and providing incentives for innovation. However, neither of these arguments can be brought to bear through empirical studies.[124] There is the inevitable argument that in the pharmaceuticals industry, patent protection prevents the proliferation of formulations and active ingredients as trade secrets which supposedly would hamper innovation and deprive the public domain of that specific information. While we agree that secrecy in pharmaceuticals is not a desirable option, we remain unconvinced that the patent system is the appropriate regulatory instrument for guaranteeing disclosure of pharmaceutical formulations and active ingredients. Pharmaceuticals are subject to additional regulatory procedures, such as market approval after presentation of the required clinical trial results, that could well also require complete formulation and active ingredients disclosure.

With nanotechnology, the concept of invention and the patent regime may fail further when considering inventions resulting from biomimetics and mimetics. These inventions will be complex machines *à* von Neumann, just like chemicals. It is this type of invention that the present substantive patent law is not equipped to deal with. Evidence of this lacuna is provided by the remedy supplied by the special treatment of chemical and biotechnology inventions. This inherent failure of substantive patent law to deal with complex machines could be invoked to explain the chemical industry's vacillation as to the suitability of the patent system for their purposes. After all, chemicals, all chemicals, including macromolecules which are beautifully illustrated by their enablement as genes, are complex machines.

Science and technology have diverged from the patent system because while the patent system was designed to deal with Cartesian machines or simple engines, science and technology have advanced and are now capable of inventing complex engines. Thus today's engineering teams are manufacturing devices which are increasingly complex and which cannot be compared with the objects manufactured in the late nineteenth and twentieth centuries. As a technological society, we have moved past steam engines and mechanical watches to digital technologies driven by complex machines components, such as those found in smart phones.

The bigger question that we see emerging from the considerations above is whether the principles of patent law concocted at the beginning of the industrial revolution at the end of the nineteenth century to accommodate the industrial fabrication of simple machines and mechanical devices are adequate and sufficient to cope with the engineering of molecular processes. We suspect that they are not and take nanotechnology as a case study to ask some fundamental questions about the foundational building blocks of patent law in a globalized, digital and ever more complex world.

[124] For a discussion of the patent system in terms of its functionality as a legal device of wide application in the light of its strengths and weaknesses see: J Philips, 'A spanner in the works - or the spanner that works? Patents and the intellectual property system' in T Takenaka (ed.), *Patent Law and Theory: A Handbook of Contemporary Research (Research Handbooks in Intellectual Property)*, Edward Elgar Pub, 2008, p. 790.

V. Diagnosis

In the this paper we looked into the broad concerns about nanotechnology patents including an examination of a patent including self-assembling peptides in electronic materials[125] that had been identified as exemplary for the concern, but soon found these not to be specific to nanotechnology. The initial concern voiced by Bowman[126] that a broad interpretation of Article 27 TRIPS may result in the monopolization of fundamental molecules and compounds via the patent system merits discussion because nanomaterials are, as we argue from an ontological perspective, for all practical purposes of science and law, chemicals.[127] Hence what is at issue is the patenting of chemicals, not the patenting of inventions issuing from technologies using methodologies and applying scientific principles associated with the conceptual narrative of *nanotechnology*.[128] In our analysis we find no evidence that either "the very broad interpretation or loose definitions used to describe nanotechnology"[129] act to weaken the protection afforded by the patent system for two reasons. First, there is no recognized single and distinct technology as such that is designated by the term nanotechnology. Instead we find that an ensemble of methods and principles under the umbrella of nanotechnology can be applied in any technological area, as can be seen by the distribution of nano-patents across a broad range of patent classifications. Second, the legal battles fought so far over nanotechnology patents have not taken issue with either invention as such, the scope of the claims, or with any issue in substantive patent law. However the concern remains that there are patents that protect the mere discovery of such objects as "human cells, umbilical cells, plant genes."[130] We reiterate that all of these concerns revolve around what constitutes chemical invention. Hence there are two fundamental issues at stake. One is what constitutes invention, and the second is what constitutes chemical invention as a special case of invention. In this paper we have identified that what constitutes chemical invention is worthy of a new appraisal in light of nanotechnology methods and the research and development drive towards the imitation of nature to invent new materials.

The concerns about nanotechnology patents are old concerns about the logic and practice of the patent law and are symptomatic of much that is dysfunctional in patent law. From our perspective there are two categories of problems that need to be addressed if one is to bring back the full functionalities of stimulating innovation, technological development and the diffusion or dissemination of technical information and knowledge. On one side we have problems with substantive patent law as to the scope of patentable subject matter, and on the other side, there are systemic problems involving patent thickets, patent pools, freedom to operate and transparency, and the complexity of emerging technologies. In this paper we

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[125] See section Self Assembling Peptides in Electronic Materials.

[126] See 5.

[127] We extend this argument to quantum dots also as these are but a subset of all man-made nanomaterials and chemicals.

[128] For a detailed discussion of the narrative dimension of nanotechnology see E Mordini, 'The narrativedimension of nanotechnology', *Nanotechnology Perceptions* vol. 3, 2007, pp. 15-24.

[129] See 5 at 313.

[130] In 5 at 311 citing Ho M. Why biotech patents are patently absurd-scientific briefing on TRIPS and related issues. London: Institute of Science in Society; 2001.

introduce the distinction between simple and complex machines as these relate to chemistry and nanotechnology, the point being that chemicals are complex machines whose behaviour is more extensive than our representational methods can describe. This distinction poses the question of what is the logical category of inventions that fall within patentable subject matter given that patent law was conceived to cover simple machines, not complex ones. This question emerges naturally because most of the problems documented elsewhere in the case law revolve around the patenting of genes which are chemicals and naturally occurring.[131] We find that the concern over nanotechnology patents should be focused elsewhere. This concern should be directed towards determining the desirability or not of maintaining chemicals as such as eligible patent subject matter.

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[131] For example see : BM Simon, & CT Scott, 'Unsettled expectations: how recent patent decisions affect biotech', *Nature Biotechnology* vol. 29, no. 3, 2011, pp. 229-230.

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