Nanomedicine in the Making
Expectations, Scientific Narrations and Materiality

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Abstract: Starting from the theoretical debate about technoscientific expectations, and based on the data collected doing ethnographic research in a laboratory of nanomedicine (in Northern Italy) operating in the field of experimental and clinical pharmacology, the paper explores in detail the relationship between anticipatory knowledge, scientific forward-looking statements and the situated practices of biomedical research in nanomedicine. In particular, I will focus on the processual dimension of scientific narrations on nanomedicine, in order to understand how future-oriented abstractions may represent a fundamental element for the local practices of nanomedical research. In doing so, and referring in particular to a socio-technical artefact called "triangle Dna origami",I develop the notion of *promissory bio-object*, as a conceptual device to improve the understanding of the engagement of anticipatory knowledge in biomedical research.

Keywords: nanomedicine; translational research; anticipatory knowledge; promissory bio-object; ethnography.

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1. Introduction

Nanomedicine as a translational science has the goal to provide cost effective novel therapies and diagnostics using the expanding world of Nanotechnology. To reach this goal the process of translating research results from labs to the clinic has to be greatly improved.
Joint European Commission (2009, 6)

What if doctors could search out and destroy the very first cancer cells that would otherwise have caused a tumour to develop in the body? [...] What if pumps the size of molecules could be implanted to deliver life-saving medicines precisely when and where they are needed? These scenarios may sound unbelievable, but they are the long-term goals of the Nih Roadmap's Nanomedicine initiative that we anticipate will yield medical benefits as early as 10 years from now.
Nih Roadmap for Medical Research

These brief, but sharp, quotations, drawn up by two major regulatory and investment authorities in the field of nanomedicine[1], clearly describe the potential implications of the 'infinitely small' for translational research in life sciences. Nanotechnologies appear to be capable of improving knowledge translation between scientific laboratories and clinical settings, and a number of new treatments and refined diagnostic tools are expected in the very near future.

In recent years, the scientific movement of nanomedicine, which emerged under the aegis of translational research, exemplifying the connection between scientific research and patient care, has become fairly significant in the field of post-genomic sciences (Baird *et al.* 2004; Tsai-hsuan Ku 2012). The proponents of translational research in nanomedicine believe that, within a relatively short time, a new set of 'smart' therapeutic tools incorporating a variety of functions, such as the controlled release and 'real-time' quantification of drugs, will soon be available to doctors and patients, enabling adaptation of therapies to the genetic peculiarities of individuals (Venugopal *et al.* 2008; Tibbals 2011).

Nanomedicine is now being promoted as a potential driver of biomedical innovation, capable of opening a therapeutic scenario in which treatments will become personalised, and individuals will take an increasingly active role in the control and maintenance of their daily well-being. In this sense, the standard view of nanomedicine, supported by the biomedical community and circulating in major scientific journals, appears to be characterised by a 'future-oriented debate' that is to be understood as the complex 'outcome' of scientific narrations, expectations, anticipations and future visions arising from the potential application of nanotechnology in the context of patient care (Grunwald 2004; Lösch 2006; Ach and Lüttenberg 2008).

The ongoing dialogue between nanotechnology and biotechnology is a topic of undoubted importance for Science and Technology Studies

[1] The first excerpt was written by a team of experts from the *European Technology Platforms on Nanomedicine* (Etpn). Etpn is an initiative promoted by the European Commission, together with a strategic alliance of private enterprises, with the aim of pursuing the application of nanotechnology within medical and clinical contexts. The second quotation, appearing in Tibbals (2011), was taken from *Nih's Roadmap Nanomedicine Initiative,* which is a platform founded and financed by the *National Institutes of Health* of the United States.

(STS). In the last decade, numerous contributions within STS have shed light on the ways in which anticipatory expectations and "forward-looking statements" (Fortun 2002) concerning scientific and technological progress may be regarded as rhetorical devices capable of attracting the attention of relevant stakeholders, such as policymakers, investors and directors of research laboratories, together with a number of financial, regulatory and symbolic resources (Brown *et al.* 2000; Holtzman and Marteau 2000; Levidow and Marris 2001; Sturken *et al.* 2004). In this florid debate, one of the most recent developments has been the growing interest in how real-time practices are performed in relation to future-oriented scientific narrations (Borup *et al.* 2006; Horst 2007).

Starting from these theoretical suggestions, and based on the data collected during an ethnographic research conducted in a laboratory of nanomedicine based in Northern Italy and operating in the field of experimental and clinical pharmacology, I explore in detail the relationship between anticipatory knowledge, scientific forward-looking statements and the situated practices of biomedical research in nanomedicine. In particular, I focus on the processual dimension of scientific narrations on nanomedicine, in order to understand how future-oriented abstractions may represent a fundamental element for the local practices of nanomedical research. In doing so, and referring in particular to a socio-technical artifact called "triangle Dna origami", I develop the notion of *promissory bio-object* as a conceptual device to enable improved understanding of the engagement of anticipatory knowledge in biomedical research.

2. Theoretical Tributaries

Anticipatory narrations and expectations regarding science and technology always involve a set of linguistic statements on particular events located within a future-oriented imaginary world, which is still incomplete, but likely to come into effect in certain circumstances (Adam and Groves 2007). Nanomedicine and translational research in general are permeated by rumours and debates outlining future life technologies, future benefits, future patients and future clinical applications (Ioannidis 2004; Thacker 2004; Martin *et al.* 2006; Wainwright *et al.* 2006; Selin 2007).

In accordance with the lively debate on the relationship between anticipatory narrations and technoscientific innovation, the last decade saw the establishment of the so-called "sociology of technoscientific expectations" (Brown and Michael 2003). This approach has been used to investigate the way in which expectations, promises and visions, by means of cultural metaphors, narrative scripts or forecasting policies (Michael 2000; Wyatt 2000; Király *et al.* 2013), are projected and manipulated in

the public sphere as a resource for driving research and development activities and change in the present (Rosenberg 1976; Van Lente 1993; Van Lente and Rip 1998; Brown *et al.* 2000).

In this theoretical framework, the emergence of post-genomic nano/biotechnologies has been interpreted as part of the construction of a new bio-technoscientific regimen, where it may find a number of cultural expectations, biomedical scenarios and promises relating to the potential revolutionary benefits of new treatments or diagnostic and clinical practices (Selin 2006; Hedgecoe and Martin 2007; den Boer *et al.* 2009; Rose and Rose, 2012; Groves 2013). Research has focused on the importance of expectations for the emergence of innovative biomedical fields, such as genomics and biotechnology (Fleising 2001; Fortun 2001, 2002), pharmacogenomics (Hedgecoe and Martin, 2003; Hedgecoe 2006), telemedicine (Rappert and Brown 2000) and information technology (Geels and Smit 2000; Wyatt 2000; Casper 2005). From an analytical perspective, the above contributions have led to a 'top-down' mapping of anticipatory narrations. In particular, the authors have addressed only the temporal cycles of emergence and partial disappearance of anticipatory rhetoric in public spaces, mainstream media or scientific journals.

In this sense, the close relationship between forward-looking statements and the local articulations of scientific research has been neglected. As a consequence, the importance of investigating the way in which scientific expectations of the "future of nanomedicine" may take on a material dimension, becoming variously incorporated into diagnostic procedures, treatment options, and new biomedical technologies, strikingly emerges.

In order to address this issue, it is useful to look at those debates which, focusing on the sociomaterial dimension of technoscientific practices (Law 1987, 1994, 1999; Mol and Law 2002; Orlikowski 2007), suggest that we should pay particular attention to the alignment between human actors, technical objects and discursive representations (Collins and Yearly 1992; Fujimura 1995; Suchman 2000).

Some authors, inspired by these contributions, have recently proposed the notion of bio-objects, in order to conceptualise how new forms of life are designed and materialised into clinically actionable devices (Webster 2011). Such a concept is useful for studying the sociomaterial process by which new biological entities (such as stem cells or synthetic biologically-based devices) are created and, at the same time, how they can shape new clinical, regulatory and commercial issues (Waldby 2006). From an analytical standpoint, bio-objects are embodiments of knowledge in the making that capture the reconstruction of the boundaries between biomedical research and clinical needs. As a consequence, they are characterised by mobility across different techno-scientific domains, such as laboratories and clinical settings (Douglas *et al.* 2012). Furthermore, in a seminal paper, Metzler and Webster (2011) have shown that bio-objects are manifestations not only of material practices, but also of hopes and expectations with regard to the possibility of strengthening the

knowledge that enhances biomedical intervention in health and illness. On the whole, this notion suggests an innovative connection between the sociology of technoscientific expectations and the sociomaterial approach, enabling investigation of the performative dimension of anticipatory knowledge.

In the following sections I will focus on the relationship between scientific narrations and materiality, in order to understand how the expectations of translational nanomedicine can be embedded into biomedical practices and materialised into nanotechnological therapeutic objects. Specifically, in order to show how the dialogue between research and care practices occurs through the mediation of scientific anticipatory narrations and expectations, I will focus on a detailed analysis of the activities involved in the design of a nanodevice, a new biological entity which can be defined as a *promissory bio-object*.

3. Case Study: The Birth of Onco_N@no

Contemporary biomedical science is concerned with the problem of improving the relationship between the laboratories and the bedside. Scientific discourse regarding translational research has recently gained growing importance in shaping imagined futures concerning the application of laboratory research in the clinic (Ioannidis 2004). In particular, as an emerging bio-technoscientific field of translational research (Tsai-hsuan Ku 2012), nanomedicine clearly reveals how scientists, doctors and researchers can occupy a temporality that is strongly biased towards the near future, through the disclosure and declaration of statements and narrations that outline possible developments in biomedicine (Birch 2006).

The articulation between bench and bedside proposed by a translational paradigm may be strongly mediated by expectations and future-oriented scientific statements. Therefore, it becomes necessary to adopt an empirical gaze aimed at understanding how anticipatory scenarios in nanomedicine will break through the walls of research laboratories and contribute to the innovation of biomedical practices. In this sense, the expectations and scientific narrations generated by the supporters of the new technological paradigm in nanomedicine should be understood as productive resources, rather than mere representative statements, which allow to shape and define the conditions for the development of clinical technologies.

Overall, this paper is based on broader ethnographic research that was conducted over a period of 5 months. The empirical material was collected through documentary analysis, in-depth interviews and the ethnographic observation of R&D activities within a laboratory of

nanomedicine called Onco_N@no[2].

Onco_N@no is a newly established laboratory, which, starting in January 2012, has gradually been incorporated within a larger care and research institute in Northern Italy that is engaged in molecular oncology. Doctor Gianni, an internationally recognised oncologist, has been the director since its foundation:

> Nanomedicine provides one of the most exciting and promising paths of research and will help us transfer laboratory discoveries into hospitals – explains Gianni, who deals with translational medicine, the aim of which is to ensure a direct contact between laboratory and patient. [...] Our goal: it's real-time monitoring of the potential side effects of a treatment, be it traditional (chemotherapy) or "smart" (with monoclonal antibodies and other biologics drugs). When I heard that I had been awarded the funding from ***, I have to admit that, after the initial excitement, I was actually quite scared. It was a positive concern though, which had to do with the responsibility of coordinating a project in which I strongly believe and that I have been relentlessly pursuing together with my colleagues. (Gianni)[3]

Gianni's considerations reveal the complexity of what must be accomplished locally to articulate a manifold and composite area of research.

> Nanomedicine, this new current, is my last challenge. What is nanomedicine then? For me, it means designing drugs. It means designing drugs in a different way, in order to make them selective for neoplastic cells, or developing devices that can be useful for treatment. (Gianni)

The utterances of Onco_N@no's director move from an anticipatory narrative level, which includes the expectations and promises involved in the development of new therapeutic nanotechnologies, to the level of everyday research practices, which must be coordinated in such a way as to confer credibility on these expectations. These two levels are, as a whole, the lenses through which Gianni observes the reconfiguration of biomedicine in the near future. He presents a scientific vision of nanomedicine as a tool for the understanding and manipulation of matter, on the nanometer scale, for the benefit of patients and therapeutic planning.

During my ethnographic investigation I followed in detail the early stages of the commissioning of Onco_N@no, which primarily involved two researchers: Beppe and Martino. Beppe, with an academic back-

[2] Persons and locations names are pseudonyms.

[3] Interview given by Gianni in January 2012 for a magazine edited by the institute that co-financed Onco_N@no.

ground in physics, had just returned from the United States to support Gianni's project, suspending his position as *research assistant professor* in the department of biology of an important science and technology institute. Beppe was then joined by Martino, a young PhD student in nanotechnology, who greatly contributed to the local translation of the anticipatory scenario proposed by the director of Onco_N@no.
In what follows, my focus will be in exploring how nanomedical expectations and anticipatory knowledge, such as statements of ideas and scientific facts, can be inscribed and embedded into biomedical practices and diagnostic and therapeutic options (Borup *et al.* 2006). It is a point of particular relevance, which helps to clarify how nanomedicine can contribute to the overall definition of biomedical research in contemporary society, and deepen the notion of promissory bio-objects as a conceptual device for the analysis of the processes that confer materiality, credibility and strength on forward-looking statements.

4. Exploring Nanomedicine through Expectations, Technology and Materiality

Since its inception, Martino and Beppe have been engaged in the *modelling*, *development* and *visualisation* of nanodevices, which are sometimes defined as "Dna origami" (Rothemund 2006) or, more suggestively, as a "Trojan horse to attack cancer" (New Scientist 2012). Technically, Dna origami can be defined as a three-dimensional structure on the nanoscale, the shape of which is arbitrarily decided by the human operator by whom it is created. The peculiarity of biochemical interactions between the molecules that make up Dna[4] makes it extremely useful matter for the construction of new forms of life that do not exist in "nature". Dna origami, developed for the first time by Paul Rothemund at the laboratories of the California Institute of Technology, have rapidly become a "promissory material" for the generation of new biomedical nanotechnologies that are capable of improving drug treatment or "drug delivery"[5]:

[4] The macromolecule of Dna consists of molecules that are called bases. The bases are linked together in an orderly way. This phenomenon is known as complementary base-pairing. The combination of two bases is called a "base pair" and is the unit of measurement used to determine the length of a Dna molecule. The principle of complementary base-pairing was first described by James D. Watson and Francis H. Crick in 1953.
[5] The concept of *drug delivery* refers to a number of approaches and technologies applied on the nanoscale, which are intended for the transport of pharmaceutical compounds to the body in order to improve the efficacy and safety of treatments (Wang and von Recum 2011).

> For drug delivery you need to build an intelligent structure. This will give you better control as compared, for example, to traditional nanotubes. You will also need to characterise this structure. Now, Dna seems to me the most suitable material. Dna is subject to early deterioration. And it is toxic, but for how long? Probably for half an hour. Whereas nanotubes, I mean... they may cause apoptosis of all cells. Nanotubes are toxic, and not only for half an hour. (Beppe)

As Beppe suggested, Onco_N@no research activities were primarily oriented towards the production of a Dna nanostructure that could act as an "intelligent vector" of a specific therapeutic molecule. The clinical rationale derives from the need to identify a number of treatment regimens that are less invasive for the human body and have a relatively low toxicity. Since the early stages of design, Beppe has framed Dna origami within a purely clinical actionability (Nelson *et al.* 2013), expressing a number of therapeutic expectations (for example, the reduction of toxicity level in drug treatments for cancer) as forerunners of his research activities:

> On the basis of this research work, I can say: "Yes, I can use this device and I know how it behaves." And then, I can implement my origami with respect to the clinical needs. That is, for example, the drug delivery. Why could Dna origami be a winning strategy for drug delivery? Because they are biocompatible. They are made with the same biomolecules that you find in our bodies. In doing this new thing, we established a few points to follow. First point, we are in a research and care institute, so we have to do something related to cancer treatment. Second point, our director has always been involved in experimental and clinical pharmacology. Thirdly, we have the patients. Therefore, cancer, patients and medications: these are the ingredients. (Martino)

Through this discursive operation, Beppe and Martino attempted to establish a material-semantic link between the clinical expectations and research activities of Onco_N@no, turning the nanomedicine laboratory into an instrument at the service of the patient. In this respect, researchers' words are pervaded by a sense of moral responsibility, demanding the adoption of explicit and demonstrable procedures, peculiar to a system of 'scientific truth' (Hacking 2009), in order to account for and justify the fact that Onco_N@no's activities move towards clinical application. It is a practice of *accountability* (Garfinkel 1967) which, in conjunction with the modeling, development and visualisation of Dna nanodevices, confers credibility on the future-oriented scientific statements that constitute the global field of nanomedicine.

Moreover, it is important to underline that both quotations elucidate how material expectations regarding translational nanomedicine outcomes enacted by Dna origami are partially shaped by the institutional setting's vision around the potential benefit of the nanodevice. At the

same time, the institutional vision is co-generated by the possibility of successfully constructing the nanodevice as a therapeutic object. In this sense, the articulation between bench and bedside, strongly supported by the translational research paradigm, is mediated by the circulation of expectations between multiple levels and domains.

4.1. Nanomedical Modeling: Centers of Calculation and Molecular Bio-design

According to the researchers' expectations, one of the nanodevices designed and developed at Onco_N@no could significantly enhance the efficacy and safety of a specific drug or therapeutic compound with which it is combined:

> The Dna triangle that I'm preparing, as you can see, is a simple structure. And it is precisely for this reason that I believe that you can have better control when you test it on blood and in patients. We need a structure that can be monitored and aggregated with a drug, that's all. If you create an origami that is too complex, you're back to square one. How do you manage to check it within the body? (Martino)

Designing the nanodevice initially involved the graphic modelling of the intended structure. Martino and Beppe were oriented in the creation of a structure having a triangular shape, hence the name triangle Dna origami (Tdo). By reason of its alleged simplicity and graphic 'abstemiousness', as Martino explained, Tdo would allow improved control by the operators when used in complex biological systems, such as the human body. However, the question of simplicity and visual abstemiousness is not to be understood as a mere technical problem. Describing his Dna molecules in familiar terms, Martino has the ability to make the subject accessible and intelligible, not only for researchers and the confined community of nanotechnologists, but also for clinicians and non-specialists that are simply interested in laboratory scientific activities, such as patients.

While I was conducting my investigation in the laboratory, it often happened to see researchers from other scientific institutes in Northern Italy (who used to visit Onco_N@no to negotiate partnerships and collaborations) showing great interest, and even surprise, with respect to the research activities of Martino and Beppe:

> Martino: So, first of all, I tried to select the best software to design my origami. I tried a few. All of them are CAD [computer-aided design] software and are free [...]. In the end, I found out that the only software I could use was this one. It is called NanoEngineer. In my opinion, it is the best software for this

application, since it also allows 3D design, whereas other software would only support 2D design. Basically, this software allows you to create your own origami.

Engineer (guest): Can you give us an idea of how you create this origami?

Martino: You need to design its structure with NanoEngineer. This way, you will have your assembled structure, also including complementary sequences of DNA. Once you have drawn the structure and you are sure about your project, you need to acquire Dna fragments, mix into solution, and then you can do the rest, that is make your reaction.

Engineer (guest): So you are telling us that the structure is automatically generated? Do you mean that the origami is automatically generated out of this indistinct mixture?

Martino: Basically, yes.

Engineer (guest): It is truly fascinating. It is really incredible how you can create the structure out of this slop. Well, considering that we live thanks to DNA, you can easily figure out why it may react like this. It is a real "wager" when you mix all these things together trying to achieve ordered nanostructures. It is something beautiful and the wager is very powerful for the clinic.

"The wager is very powerful for the clinic": the epilogue of this conversation shows how the research activities in which Martino is engaged require the ability to manage scientific knowledge and technologies, as well as expectations, in the form of the scientific wager, revolving around nanomedicine. From the conversation between Martino and the chemical engineer, we learned that the design and production of the nanodevice implied a composite work of digital and organic, and between clinical expectations and laboratory practices, in order to develop new treatment strategies.

The modelling of Dna origami is articulated through a process of graphic design using an open source; computer-aided design software called *NanoEngineer-1* (Fig. 1).

The software used by Martino conceals a sophisticated corpus of scientific knowledge in the field of molecular biology behind an extremely simple and intuitive user interface. NanoEngineer-1 makes it possible to simulate the biological process of Dna reproduction and synthesis, since the software developers incorporated in the application a codified and formalised knowledge base regarding the complementary pairing of Dna sub-units. This means that the operator can generate 3D images of Dna on a nanoscale, which is potentially achievable in the laboratory.

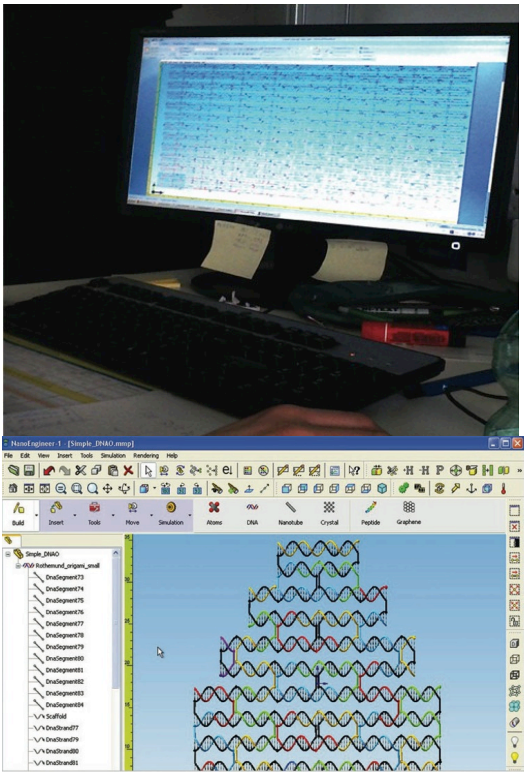

Fig. 1 – Modelling of a nanomedical device with Nano_Engineer-1

However, when modelling the TDO, Martino's activity was not limited to the use of the software. Although it may sound like a highly technical activity, opened by software potential in itself, the modelling required the juxtaposition of other handmade graphic elements, such as drawings, prototypes and proofs (Fig. 2a and 2b).

These were later collated in the laboratory journal and, to some extent, they express Martino's scientific creativity, which confers shape and materiality on the expectations of nanomedical devices.

Such representations, sketches and drawings, may be regarded as central elements of mediation in building Tdo digital images, and constitute the space in which scientific ideas regarding the future are visually refined.

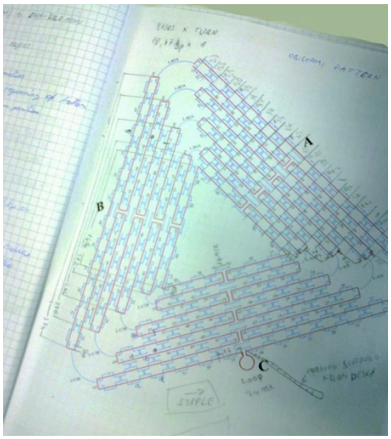

Fig. 2a – Graphic drafts of the nano device

Fig. 2b – Graphic drafts of the nano device

In other words, a specific medical nanotechnology that initially escapes the sensitive perception, becomes present, credible and, above all, achievable, through laboratory practices. In this respect, the goal of the graphic exploration of Dna molecules is not merely theoretical, nor simply attributable to the reconfiguration of new knowledge on Dna properties on the nanoscale. Despite the fact that, to a certain extent, nanomedicine wishes to ascertain the implications of biological processes on an atomic scale, the main goal of Onco_N@no research activities is to make an attempt to actively manipulate organic matter for the design of new therapeutic strategies.

Within this experimental frame, the computer application used by Martino appears to be particularly relevant. While incorporating codified and formalised expert knowledge, the software serves as a "centre of calculation" (Latour 1986, 1987) that is standardized and shared by the international scientific community. The standardization of modelling procedures conveyed by the software and the digital images produced by Martino can meet the approval of the reference scientific community: Tdo digital images do not pertain to the level of imagination, but are self-evident scientific representations of the generative potential of Dna.

Thanks to the knowledge base incorporated in the software and recognized by the international scientific community, the blurred and antithetical boundaries between "imaginary" and "scientific" are reassembled within an epistemologically consolidated regime of disciplinary truth (Knorr-Cetina 1981). In this way, researchers have constructed a "digital object" (Monteiro 2010) as intermediate scientific evidence that helps to recompose the discursive level of future nanomedicine with that which is

experimental. This means that the image can also be shared, displayed, and potentially translated into clinical practice, conferring credibility on the nanomedicine scenario.

4.2. Development and Visualization of Nanodevices: Seeing Is Believing

As described in the previous section, the concept of Dna, which is the constituent material of the nanodevice, pertained to a computational representation during the modelling phase. It was a computer-based, or *in silico*, simulation of the process of synthesis and aggregation of the subunits forming the Tdo. The graphic design stage was followed by the *in vitro* development of the nanodevice, in the form of a biological sample. The Tdo development path was articulated in a number of experimental activities, which required the manipulation of short sequences of Dna, the so-called oligonucleotides, in order to confer a biological and material status on digital images.

The Dna sequences have the property to aggregate into the ordered and predefined structures that are called Dna origami through a biochemical reaction induced by heat (annealing reaction). After designing the image on NanoEngineer-1, Martino had to "catalogue" the different Dna sequences required for the preparation of the reaction that would lead to the formation of the desired nanodevice. The software incorporates a dedicated tool that automatically generates a list of nucleotides constituting the Tdo. This list is nothing more than a long list of letters indicating nucleotide aggregations in the form of "GATGG" etc. (Fig. 3). This means that the nanodevice, following *in silico* simulation, is translated from a visual and graphic language (the image of the triangle) into a conventional and standardized alphabetic language, taking on a new informational dimension. When preparing the annealing reaction, based on a "trial and error" approach, the researcher defines an experimental protocol providing the instructions, methods, materials and sequences of actions necessary for the *in vitro* development of Tdo.

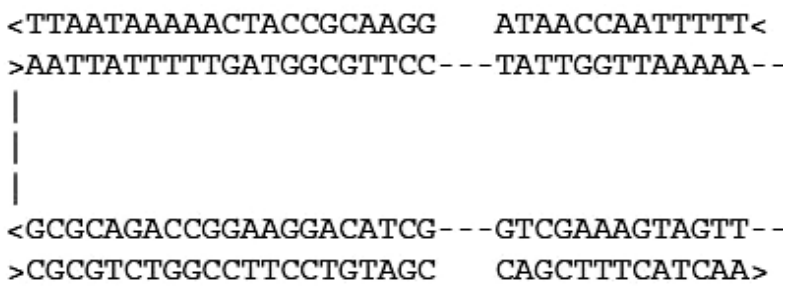

Fig. 3 – Example of nanodevice informational representation

The overall coordination of the reaction for assembling Dna sequences is particularly laborious, and recursively interweaves the subsequent activities of visualization and characterization of TDO. After completion of the annealing reaction, Martino obtained a set of biological samples, in which he may have reasonably expected aggregation of Dna sequences for generation of the nanodevice. At this point, it is necessary to adopt a number of experimental procedures to verify the formation of the desired nanostructures. This verification phase also has a characterization function, since it allows the estimation of some of the biochemical properties of the product obtained from the reaction. The visualization of the nanostructure is achieved through an experimental procedure that is fairly consolidated in molecular biology laboratories: electrophoresis. This technique for the analysis and separation of Dna molecules enables the production of very particular images (Fig. 4), as well as a further graphic and visual representation of the nanodevice.

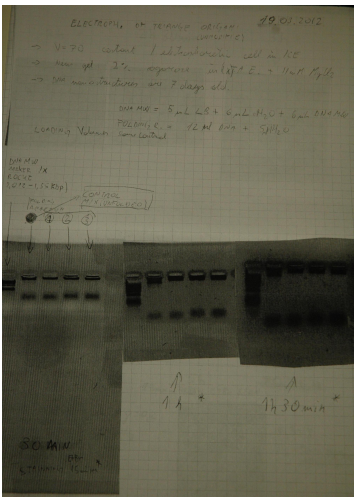

Fig. 4 – View of the nanodevice after electrophoresis

The visual representations of the nanodevice, obtained through electrophoresis and subsequent exposure of Dna inside a photographic device, are configured as 'light/dark bands' and form visual objects of mediation between the computational and purely biological status of Tdo, achieved through experimental laboratory practice. As shown in figure 5, Martino is comparing the image of his nanodevice with one that is standard, or a molecular weight marker, in order to assess whether the resulting "light/dark bands" are compatible with the formation of Tdo. If

the evaluation of the 'bands' does not meet the expected outcome, the protocol should be reviewed, and further development and characterisation activities should be defined.

Beyond the technical aspects, what is interesting is the use of a highly standardised set of technologies within an experimental process that incorporates a potentially high degree of innovation. Although Martino is engaged in an innovative, and therefore unstable and lacking in established standard procedures, field of nanomedicine, it becomes clear how the production of scientific knowledge is connected not only with Onco_N@no-situated purposes and the information obtained from the materials used, but also with a set of knowledge and practices that have been "inherited" from biomolecular scientific culture. In this sense, while

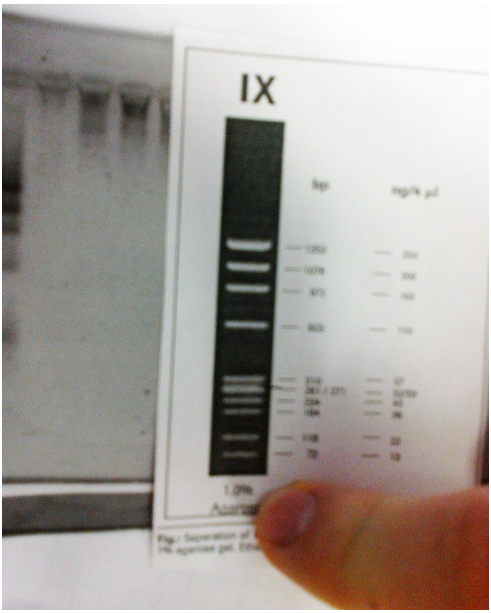

Fig. 5 – Standards for the evaluation of the nanodevice

identifying an ambiguous and opaque biological entity, Tdo calls for the alignment of a set of experimental data and scientifically established technologies in order to manage its controversial and "esoteric" dimension. In other words, in order to assess the outcome of the experimental process for the construction of the nanodevice, and determine whether it also has a material status, in addition to being purely discursive and informational, it is necessary to identify a set of reliable procedures to allow its visualisation. To some extent, Martino implements an established scientific repertoire within an emerging scientific field, in order to give the

procedures a robust epistemological status, and to naturalise a number of emerging scientific practices that still remain opaque and uncertain (Collins 1981; Collins and Pinch 1993).

Overall, the activities of modelling, development and visualisation of Tdo can be understood as explicit scientific procedures that allow the anchoring of the debate on nanomedical future to the local biomedical setting. The outcome of these activities was the production of a new biological entity, a bio-object, which conveys and materialises the set of expectations revolving around the foundation of the laboratory.

This reflection, in accordance with other contributions, documents the central role of visual representation in nanomedicine research (Mestrutti 2011; de Ridder-Vignone and Lynch 2012). We can see how expectations and scientific imaginings are turned into images as a means of construction and communication of objectivity (Daston and Galison 1992, 2007). In particular, the graphic representations of the Tdo enable an important dimension of the scientific images that Burri called *visual persuasiveness* (Burri 2012, 53). This visual dimension emphasises the relevance of images as scientific evidence that make visible the natural world (Frow 2012); or rather, in being considered objective and true, as an emanation of the purity of scientific method (Perrotta 2012). In other words, the scientific images of the bio-object allow us to juxtapose and connect scientific views and practices of biomedical research: this means that anticipatory scientific narrations on translational nanomedicine, which is to be understood as a science lying on the borderline between the clinical world and scientific laboratories, are visualised and translated from a merely discursive level to a level of feasibility and scientific manageability.

5. The Emergence of Promissory Bio-objects

Scientific research in Onco_N@no identifies a broad process in which Martino and Beppe sought to consolidate an experimental procedure for the construction of a new biomedical nanotechnology that is capable of expressing a set of expectations and visions supporting the possibility of translating nanotechnology into patient care devices.

As mentioned above, this process was implemented within a context that extends well beyond the four walls of the laboratory. The technoscientific world of Beppe and Martino is populated not only by human actors "at hand", but also by objects and technologies of various technical complexity that are inherent in scientific practice: Dna (which connects the laboratory with the community of molecular biologists), *NanoEngineer-1* software (which connects Onco_N@no with the community of nanotechnologists), the laboratory journal (which collects all activities and data that will be published and made available to the international community) and expectations regarding the use of nanodevices (which

connect the laboratory with the clinical world). However, when translated from the public sphere to the confines of local laboratories, expectations and scientific visions of nanomedicine become, principally, technical issues that are addressed through the development of experimental standardised procedures.

Through the R&D of Tdo, and the subsequent practices of visualisation and materialisation, that which is exposed to the scientific community is not simply a new life technology, but a broader sequence of events, something far more abstract that concerns the configuration of a new biomedical approach to the body and disease:

> Research in nanomedicine means speculating on treatments that will save you from going to the hospital every day. This is the most powerful aspect. I believe that, otherwise, there would not be enough added value. I mean, what's the point of replacing a treatment with another one, if there is no guarantee of improvement? Therefore, I believe that having something that is not particularly or overly invasive for the patient is paramount. Our goal is not only to increase life expectancy of patients with cancer. What we want to achieve here is defeating cancer. (Beppe)

With clarity and conciseness, Beppe emphasises the scientific challenge undertaken by the director of Onco_N@no: the development and testing of nanodevices operating within the body that are capable of redefining the trajectories of patient bio-medicalization. In this sense, the innovative content of translational nanomedicine lies not so much in the direct manipulation of matter at an atomic level, but in the development of techniques and methods for the creation of devices for molecular intervention, or rather the shaping of "programmable", clinically relevant and promising biological entities.

From a theoretical perspective, Tdo, similar to other nanodevices created in biomedical laboratories, is the product of diverse practices for understanding and improving human life, namely with the creation of tangible objects that can be used in the clinic to govern the development of pathological processes (Webster, 2012). These bio-objects also tend to blur the conventional boundaries between "human" and "non-human", which are traditionally assumed by life sciences in general (Holmberg *et al.* 2011). The use of Dna as 'natural', programmable and bio-compatible material allows the location of the bio-object within a hybrid domain that exceeds the dichotomy between the natural and artificial character of therapeutic intervention.

One last aspect of particular relevance is associated with the knowledge they incorporate. As previously discussed, the practices of construction of the bio-object were triggered by the promissory debate on a nanomedical future that is populated with a number scientific views and expectations regarding the possibility of intervening in therapeutic pathways with new nanodevices. More precisely, expectations and future-

oriented scientific narrations appealed to biomedical experimental activities, so that the continuous reproduction of their meaning by way of practical use bestows their material stability and credibility. In this respect, the emerging biomedical domain is not generated by biomedical expectations and anticipatory narrations. The generative dimension lies, instead, in the relationship between anticipatory narrations and local experimental practices, where the promissory bio-object is a relational and emerging effect of a contingent technoscientific system that is only partially stable.

Therefore, the process of Tdo materialisation should not be understood in finalistic terms, as a scientific fact of linear innovation and development, but as the local and contingent product of an ecology of actions, where expectations and future-oriented biomedical narrations provide a resource to support situated practices. At the same time, the images of the bio-object represent some type of mediators of sense, allowing the communication and actualisation of anticipatory biomedical narrations.

Overall, the theoretical juxtaposition of the material and anticipatory/discursive dimensions allows the definition of an analytical space that is outlined by the concept of promissory bio-objects. This reveals how anticipatory narrations and scientific views shall not remain mere discursive representations, but can return a set of images capable of feeding back on the present, directing the actions and intentions of social actors engaged in the practices of biomedical research.

The analytical potential of the concept of the promissory bio-object lies in the ability to investigate multiple forms of materialisation of expectations and scientific views, which find, in R&D activities and in the materiality of life technology, the ideal conditions for actualisation. This means that expectations are activated as long as they provide an instrument for supporting the local set of contextual elements for the articulation of research practices. Situated practices, in turn, give back credibility and materiality to the discursive dimension that forms the basis of anticipatory statements.

Finally, this concept reveals how contemporary biomedicine and the contextual processes of bio-medicalization are built through a process of alignment of different elements (data, laboratory tests, technologies, scientists, doctors and narrations), whereby the practices of translational research in nanomedicine intertwine with anticipatory knowledge, visions of the future and visual representations, providing an opportunity to investigate the relationships that develop between scientific narrations, situated practices and technologies.

6. Final Remarks

In this paper, nanomedicine has been framed as an emerging field in the cooperation between human actors and technological devices, scien-

tific images, linguistic resources and discursive practices, in order to understand how expectations and scientific narrations can be addressed and coordinated within experimental contexts, where biomedical knowledge and new therapeutic indications are produced and shared. Indeed, the analysis of nanomedicine showed well, as the aspirations and expectations take shape in processes in which researchers are pursuing specific objectives, experiencing what is translational nanomedicine, and representing it as a concrete possibility.

With reference to the daily activities for building a nanodevice, I tried to show how the future can be considered as a discursive arena densely populated with claims, interests, views on medicine and representations of bodies and treatments, which are recursively translated into present courses of action through the situated practices of biomedical research. If, on the one hand, these practices draw on anticipatory visions, on the other hand they confer robustness by attempting to generate new technologies that incorporate planning qualities strongly biased towards the future.

The theoretical perspective outlined in this contribution led to the formulation of the notion of promissory bio-objects as a conceptual device that proves useful for investigating the relationships between the anticipatory narrative level and the materiality of scientific activity. This helps to clarify how an emerging biomedical domain, with blurred and changing boundaries, is legitimised and made scientifically credible, that is, it is capable of generating innovative technologies. Ultimately, promissory bio-objects show a hybrid character that allows joint analysis of human actors, technologies and anticipatory knowledge, as the fundamental and constitutive element of the experimental processes peculiar to contemporary biomedical research. Expectations and scientific views are not mere cognitive issues, but elements materially embedded in the ongoing action and routines.

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