Collective theranostics and postgenomics entrepreneurship: rethinking innovations as knowledge ecosystems built by complex collaboration

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"to realize such a vision of 'collective theranostics', we need to understand how complex collaboration is unfolding in postgenomics scientific entrepreneurship in life sciences, both in realizing science and responding to its impacts."

"The very way we formulate the problem is part of the problem … How you ask questions determines the answer." [1].
Slavoj Žižek
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Getting the innovation climate right: tenets of postgenomics entrepreneurship

Some might think science is a romantic endeavor. The classic 'Edisonian' lens of science has advanced precisely that vision: 'the lone genius'. While this (false) metaphor of solitary scientific practice in a laboratory detached from society has prevailed for the past 400 years since the Enlightenment, 'game changing' transformative ideas do not hatch in a vacuum. Science and innovation are inherently social, political and collective activities [2–6,101]. They require a favorable innovation climate or milieu, be it information systems, crossfunctional knowledge teams, understanding of organizational behavior, healthcare management, social and even meteorological climate [7,8]. The building and sustenance of research infrastructures and scientific discoveries can be stifled when these forces intersect and interact unfavorably.

Theranostics is the merger of therapeutics with diagnostics in the current era of postgenomics data-intensive life sciences [9–12]. As suggested in the quote above, how we formulate the scientific questions in theranostics – as a solitary or collective activity – will be one of the most crucial drivers of innovation. Prainsack notes in her interview, for example, that theranostics may be a game changer as it entails new ways of 'doing science' [12]. Indeed, far from being a solitary research led by individual scientists, theranostics knowledge is truly transdisciplinary, application and collective innovation-oriented, and coproduced in multiple scales and locales, both inside and outside academia [12,13].

In this editorial, we underscore that whenever knowledge traverses disciplinary, ontological, epistemological (i.e., ways of knowing; how do we know what we know?), organizational, political and geographical boundaries, the need for

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complex collaboration emerges. Complex collaboration can be an enabler or barrier when researchers from different disciplines need to work closely together over extended periods and across organizational, epistemological and interest boundaries to generate solutions.

In order to realize such a vision of 'collective theranostics', we need to understand how complex collaboration is unfolding in postgenomics scientific entrepreneurship in life sciences, both in realizing science and responding to its impacts.

Postgenomics innovations as knowledge ecosystems

For collective theranostics to move from idea to innovation, the following four cases illustrate the broader importance of the complex collaboration as a driver of postgenomics innovation, and importantly, how little we currently know about these collaborative processes that underpin much of the large-scale life sciences R&D in the 21st century. Moving forward, the theranostics field and postgenomics data-intensive life sciences community undoubtedly need to empirically examine the ways in which complex collaboration is materializing in these examples summarized in the following sections.

Complex collaboration as an enabler for collective innovation: lessons from the Spanish cucumber scare

Evidenced by various open science initiatives connected by digital media and Web 2.0, postgenomics knowledge is produced in a highly 'distributed' manner – extending well beyond the cloistered hallways of academia or the laboratory bench space in developed countries [13]. Hence, for data-intensive postgenomics innovations, such as theranostics, to have a compelling case for population health and bioeconomy, both people and technology need to be connected in order to achieve a form of 'knowledge ecosystem' and 'collective intelligence' that is far more effective than any individual or singular group of people and computers. The collective nature of postgenomics distributed science has been exemplified in the follow-up to the gastrointestinal infection outbreak in several European countries in May 2011:

This [the infection] *spread through several European countries and the US, affecting about 4,000 people and resulting in over 50 deaths. All tested positive for an unusual and little-known Shiga-toxin–producing* E. coli *bacterium. The strain was initially analysed by scientists at the BGI-Shenzhen in China, working together with those in Hamburg, and three days later a draft genome was released under an open data licence. This generated interest from bioinformaticians on four continents. Twenty-four hours after the release of the genome it had been assembled. Within one week two dozen reports had been filed on an open-source site dedicated to the analysis of the strain* [14].

This example, dubbed the 'Spanish cucumber scare' (because the bacteria were initially thought to have come from cucumbers produced in Spain), shows how massively collaborative science can be realized within weeks because of a global and open science effort. While this is inspiring for theranostics, the parameters of complex collaboration that will enable collective action across the vast range of disciplinary, ontological and epistemological boundaries are virtually unknown at the present time.

Complex collaboration for unanticipated potential impacts of theranostics: case of prenatal diagnostics

The existence of cell-free DNA derived from the fetus in the plasma of pregnant women led to the idea that noninvasive fetal DNA analysis – obtained from maternal blood – can allow assessment of fetal genotype and chromosomal makeup. Cell-free fetal DNA analysis has recently been used as part of prenatal screening of sex-linked and sex-associated diseases, rhesus D incompatibility and prenatal detection of Down's syndrome [15].

While theranostics experts predict that cell-free fetal DNA analysis may lead to a change in the way prenatal assessments are made, we need to bear in mind that every first-order action has second-order consequences. In a study of the trends on selective abortions of girls in India, the conditional sex ratio for second-order births when the firstborn was a girl fell from 906 per 1000 boys in 1990, to 836 in 2005 [16]. By contrast, there was no significant decline in the sex ratio for second-order births if the firstborn was a boy [16]. Collectively, this tells us that the study of complex collaboration is needed, not only as an enabler for theranostic tests and postgenomics life sciences, but also to respond to unintended effects of knowledge-based innovations as they cross social, cultural and disciplinary boundaries.

Complex collaboration between infrastructure science & discovery science

Despite the long-standing emphasis on discovery science over the past four centuries, postgenomics theranostics R&D firmly depends on an infrastructure science, such as population biobanks, digital databases and standards, to name a few. There are a number of sharp contrasts in how infrastructure science and discovery science develop and sustain their practices, not to mention the vastly different value systems they are embedded in. For example, postgenomics infrastructure science is built by collective action and values such as citizenship whereas discovery science has been typically understood as the product of an individual scientist, driven by individual recognition that tended to promote what is often dubbed as the empire-building and overbearing 'α-personalities' (see below). Indeed, such nonreflexive α-leadership has been endemic in traditional locales of knowledge production (e.g., academia, industry and governments) by scientists, philosophers, social scientists and bioethicists alike. Never before in the history of scientific practice have such potentially conflicting values, leadership tenets and scientific practices intersected, both spatially and temporally, with the firm juxtaposition of infrastructure science and discovery science in the postgenomics era. Hence, complex collaboration is an important prerequisite to seamlessly link infrastructure science to theranostics discovery science.

Complex collaboration for leadership in postgenomics science: beyond the α-personality

It is interesting to note that the traditional concepts of leadership within expert communities have been metaphorically (and falsely) framed as a card-carrying academic scientist or nonreflexive α-philosopher uninterested in the empirical context or genealogy of scientific knowledge. However, the rise of infrastructure science in the postgenomics-era (e.g., population biobanks) is driven by vastly different and nurturing 'β-personality' type human values, such as solidarity, reflexivity and mutual respect that are essential to develop the biocommons that drive theranostic discoveries. These ostensibly softer but equally powerful human qualities are now challenging the postgenomics scientists: both α-(dominant and self-serving) and β-(nurturing and reflexive) personal qualities need to be cultivated but – in the same person – by virtue of immediate juxtaposition of infrastructure science and theranostic discovery science in the postgenomics era. However, this is another reason why complex collaboration will be necessary to accelerate such hybrid α/β-leadership to be embodied in a postgenomics science practitioner, and as new knowledge emerges at the interface of infrastructure and discovery science. While the emergence of such new hybrid forms will probably be contested by conventional expert communities, postgenomics entrepreneurship will continue to shape the old and paternalistic notions of leadership in ways that are unprecedented.

Concluding remarks

The idea of collective innovation – dynamic teams working independently as well as together, sharing data and ideas in real time – is relatively new in medicine and bioscience that hitherto tended to rely on the 'Edisonian' metaphor of science for centuries. Complex collaboration will be an important driver of collective innovation that underpins postgenomics entrepreneurship. Time is ripe to examine the ways in which complex collaboration is unraveling among the theranostics knowledge workers as this postgenomics field emerges.

The rise of complex collaboration as a central pillar of the postgenomics knowledge-based entrepreneurship invites a multitude of innovation actors to be more reflexive towards their habitus – that is, cognizant of how their own existing values and unchecked political and social assumptions – could affect their field [17,18]. Rather than subscribing to the 'card-carrying' protective membership of disciplinary tradition, postgenomics innovations would be served well by cultivating greater reflexivity among the innovation actors and narrators, be they scientists, social scientists or humanists [19].

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